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WASTAGE AT SEA OF AMERICAN PLAICE (*HIPPOGLOSSOIDES PLATESSOIDES* (FABRICIUS)) IN THE SOUTHERN GULF OF ST. LAWRENCE FISHERY IN THE 1970s

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Wastage at sea of American plaice (*Hippoglossoides platessoides* (Fabricius)) in the southern Gulf of St. Lawrence fishery in the 1970s.

by

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ABSTRACT

Halliday, R.G., D.E. Hay and K.I. Metuzals. 1989. Wastage at sea of American plaice (Hippoglossoides platessoides (Fabricius)) in the southern Gulf of St. Lawrence fishery in the 1970s. Can. Tech. Rep. Fish. Aquat. Sci. 1663: vii + 36p.

Small otter trawlers in the southern Gulf of St. Lawrence groundfish fishery in 1976 discarded 54% by weight and 76% by number of their catches of American plaice. Danish seiners discarded 43% by weight (66% by number). Total discards from all small, locally-based, vessels (i.e. including those using miscellaneous other gears) were estimated at 45% by weight (68% by number), or about 6,000 t. There also were discards from large trawlers but these were not sampled. Discards were composed of small plaice mainly between 20 cm and 35 cm, with a mean length of 27.0 cm and a mean weight of 207 gm. Sex ratio in catches was about 1:1, but about 90% of the males and about 50% of the females caught were discarded. As a result, 80% of landed fish were females and 60% of discards were males. Discards were 3 to 12 years old, with a modal age of six. The estimated length at which 50% of the catch was discarded in 1976 was 32 cm, corresponding to an age of 8.5 yrs. Less extensive discard data for 1972 and 1979 indicated that discard rates were lower in these years than in 1976. The primary cause was probably a change in population structure. The discard rate peaked about 1976 as strong year-classes recruited into the fished stock. Records of mesh size in use were inadequate to evaluate the impact of mesh size changes on catch size composition. The data indicated that an increase in 50% cull length occurred in the 1970s but this could not be firmly established. Differences in discard quantities between otter trawlers and Danish seiners in 1976 reflected differences in gear, but not necessarily in mesh, selection. The 50% gear selection length for otter trawlers was estimated at 24.5 cm, while that for Danish seiners was 25.5 cm. The primary differences in culling practices in 1976 were associated with area fished, probably reflecting fish size preferences at adjacent ports of landing.

RÉSUMÉ

Halliday, R.G., D.E. Hay and K.I. Metuzals. 1989. Wastage at sea of American plaice (Hippoglossoides platessoides (Fabricius)) in the southern Gulf of St. Lawrence fishery in the 1970s. Can. Tech. Rep. Fish. Aquat. Sci. 1663: vii + 36p.

Dans le sud du golfe du Saint-Laurent, les petits bateaux qui pratiquent la pêche du poisson de fond au chalut à panneaux ont rejeté 54 %, en poids, ou 76 %, en nombre, de leurs prises de plie canadienne en 1976. Pour les bateaux qui pêchent à la senne danoise, les rejets de plie canadienne représentaient 43 % du poids (ou 66 % du nombre) des prises. Au total, les rejets de tous les petits bateaux locaux (y compris ceux qui utilisaient divers types d'autres engins) étaient chiffrés à 45 % du poids (68 % du nombre) des prises, soit environ 6 000 t. Il y a eu également des rejets de la part des gros chalutiers, mais on ne les a pas échantillonnés. Les plies rejetées mesuraient pour la plupart entre 20 et 35 cm, la longueur moyenne d'établissant à 27 cm et le poids moyen à 207 g. La répartition des sexes dans les prises était d'environ 1:1, mais environ 90 % et 50 % respectivement des mâles et des femelles capturés ont été rejetés. Il en résulte que 80 % des poissons débarqués étaient des femelles et que 60 % des poissons rejetés étaient des mâles. Les poissons rejetés avaient de trois à douze ans, l'âge modal étant de six ans. On estime à 32 cm la longueur à laquelle correspondait un rejet de 50 % des prises en 1976, ce qui représente un âge de 8,5 ans. Des données plus sommaires sur les rejets effectués en 1972 et en 1979 révèlent que les taux de rejet furent plus bas au cours de ces années qu'en 1976, la cause première en étant sans doute un changement dans la structure des stocks. Le taux de rejet a atteint un niveau élevé en 1976, année où de fortes classes d'âge ont été recrutées à la pêche. Les données sur la grosseur de maillage utilisée n'ont pas permis d'évaluer l'effet d'un changement de grosseur des mailles sur la taille des prises. Elles révélaient une augmentation dans la longueur à laquelle 50 % des prises étaient rejetées au cours des années 1970, mais ce phénomène n'a pas pu être attesté de manière sûre. En 1976, les différences dans les quantités de rejets entre les bateaux qui pêchaient au chalut à panneaux et ceux qui utilisaient des sennes danoises correspondaient à des différences dans la sélectivité des engins, mais non nécessairement dans la sélectivité de maillage. On évaluait à 24,5 cm la longueur à laquelle 50 % des poissons étaient retenus par le chalut à panneaux, tandis que dans le cas de la senne danoise, cette longueur était de 25,5 cm. Les différences relevées dans les critères d'élimination en 1976 ont été associées aux zones de pêche et dénotaient probablement des préférences quant à la taille des poissons dans les ports de débarquement locaux.

INTRODUCTION

The southern Gulf of St. Lawrence, Div. 4T of the Northwest Atlantic Fisheries Organization (NAFO), supports a large population of American plaice (Hippoglossoides platessoides (Fabricius)). On the basis of tagging and meristic data Powles (1965) concluded that these plaice formed a biologically discrete stock. He recognized two main groups within the stock which mixed little as adults, a northern or "Miscou-Magdalen" group which included fish from Chaleur Bay, Shippegan Gully and Orphan Bank regions, and a southern or "Cape Breton" group which included fish from George Bay to St. Paul Island (Fig. 1). In summer, plaice are most abundant in depths of 40-100 m, but in winter most occur in 180-460 m along the edge of the Laurentian Channel. Movement offshore to deeper water begins in October and is complete by January. Return movement begins in April and is complete by late-May or early June, with individual fish tending to return to the same areas each summer (Powles, 1965).

Otter trawling was introduced to the southern Gulf of St. Lawrence groundfish fishery in 1947 and expanded rapidly (Jean, 1963). Danish seining began in 1958 (Powles, 1969). Prior to 1947, plaice were taken incidentally on hook and line gear fished for cod. These were all large fish, 40-60 cm in length, and total landings did not exceed a few hundred metric tons (t) annually (Powles, 1969). Subsequent to the introduction of otter trawling, landings increased greatly, reaching a peak of about 12,000 t in 1955. Landings have been about 10,000 t since then, with little inter-annual variability.

When otter trawling was introduced to the fishery trawl mesh size was not regulated, but the common practice was to use a codend mesh size of about 75 mm (3 inches). This resulted in capture of many plaice below marketable size and these were discarded at sea (Jean, 1963). Minimum codend mesh size regulations for otter trawls were first introduced in the southern Gulf of St. Lawrence groundfish fishery in 1957. However, Jean (1963) found that these regulations had little effect on discarding of plaice from New Brunswick otter trawlers. Powles (1969) confirmed Jean's results for otter trawlers, but suggested that a smaller proportion of the catch of Danish seiners was discarded and implied that season and area fished were also factors which caused differences in quantities discarded. Powles (1969) demonstrated that virtually all discards were dead when returned to the sea from commercial vessels and thus represented a loss of potential yield.

In 1976, a field project was conducted to obtain estimates of plaice discards in the Div. 4T groundfish fishery. Sampling was designed to include different areas and the two main vessel types employed, small otter trawlers (less than 150 gross registered tons (grt)) and seiners, to examine Powles' (1969) conclusions. The primary objective, however, was to quantify fishery removals from the stock as a basis for describing the impact of fishing on population dynamics. This work was done in anticipation that further controls on fishing for Div. 4T plaice would be implemented as part of a Northwest Atlantic-wide scheme of total allowable catch (TAC) controls. Such controls were, in fact, established for 1977 and subsequent years. The present paper describes the results of the 1976 project and also presents, for comparative purposes, discard data collected on a much smaller scale in 1972 and 1979.

MATERIALS AND METHODS

Commercial landings for Div. 4T were obtained from NAFO (previously ICNAF - International Commission for Northwest Atlantic Fisheries) Statistical Bulletins. In addition to landings recorded as American plaice, 90% of landings recorded as "flatfish-not specified" were also considered to be plaice based on observations by Department of Fisheries and Oceans (DFO) scientific staff. The Canadian unit area system (Fig. 1B) provides landings records on a geographic scale finer than NAFO division. However, assignment of landings to unit area of capture proved to be incomplete for 1976. For small locally-based vessels, i.e. those of tonnage classes (TC) 1-3 (less than 150 grt), unassigned seiner and otter trawler landings were 40 and 20% respectively. These were prorated among areas (within each gear type) on the basis of assigned landings. Landings in 1976 by Maritimes-based large trawlers (TC4+, i.e. larger than 150 grt) which were reported by unit area came from F and K, and it was assumed that the remainder, and landings of Newfoundland-based large trawlers, also came from these unit areas.

The Marine Fish Division port sampling programme gave special emphasis to American plaice shore sampling in Div. 4T in 1976, resulting in 47 samples being collected. These provided 9,400 fish measurements and 1,800 age readings. To estimate size and age compositions of landings by sex, landings and sampling data were grouped by unit areas (Table 1) which corresponded to fishing areas (see below). All small otter trawler landings were weighted by samples from KLNOQ because no samples were

available for other areas. The totals of size and age compositions of small trawler and seiner landings were prorated to account for the 1,100 t of plaice landed by vessels using other gear types, as the one longline sample collected was deemed unlikely to represent these adequately. The compositions of large trawler landings were then added to give compositions for all Div. 4T landings in 1976.

Stratified-random bottom trawl surveys, which have been conducted throughout Div. 4T by research vessels each September since 1971 (Halliday and Koeller, 1981), provide estimates of plaice population biomass and size and age structure by sex. Strata 15-29 and 31-39 were grouped in analyses to approximate the areas inhabited by Powles' northern and southern groups.

Most of the discard data were collected in 1976 by MacLaren Atlantic Ltd., a consulting company, under contract to the Department of Fisheries and Environment (now the Department of Fisheries and Oceans) of the Government of Canada. In that study, observers were placed aboard 47 trips of commercial fishing vessels, 19 otter trawler and 28 Danish seiner trips, fishing from the ports of Caraquet and Shippegan in northern New Brunswick, Souris in Prince Edward Island, and Cheticamp on Cape Breton Island, between 18 August and 6 December. (The difference between Danish and Scottish seining is minor and mainly concerns the method of hauling the gear. The distinction in fishery statistics between vessels using the two methods is not reliable, and all seiners are referred to here as Danish seiners.)

Vessels from Caraquet and Shippegan which had observers aboard fished mainly in the area immediately outside the Bay of Chaleur to the east of Miscou and Shippegan Islands in the Shippegan Gully area - unit area N (Fig. 1). Fishing extended into the western part of area K and the northern half of area L. This fleet also fished within Chaleur Bay (area M). Within these areas, trawlers and seiners fished much the same grounds. Observed Danish seiners from this fleet did a small amount of fishing around the Magdalen Islands (area F) and made one trip to the western Cape Breton area (area G). All observed vessels from Souris were trawlers and all fished locally in area G between Souris and George Bay. Observed Cheticamp vessels, all of which were seiners, also fished locally in area G in the vicinity and to the east of Cheticamp. The observed vessels reflected the structure of the fleets at these ports, the Souris fleet being composed of trawlers, the Cheticamp fleet of Danish seiners, and the northern New Brunswick fleet of both. The only fleet other than the ones observed, which persistently conducted a significant fishery for plaice in Div. 4T, was that of Quebec based on the Gaspé Peninsula and on the Magdalen Islands.

Based on observed trips, the two main fishing areas for plaice in Div. 4T were KLMN and G, which corresponded to Powles' (1965) northern and southern population groups. Area F, which supported a small fishery, is geographically intermediate. Powles (1969) suggested that area M (Chaleur Bay) plaice may differ in population size structure from those in adjacent N. Thus the four geographic areas KLN, G, M, and F were considered separately for analysis.

On four of the 47 trips observed, the vessel fished two of the major fishing grounds used for analysis. The data for the two parts of these trips were summarized separately giving 51 sets of observations for use in analysis. Not all 51 trips or part-trips had complete data so appropriate subsets of trips were used in different parts of the analysis.

For each fishing set, observers obtained from vessel captains the location, depth and duration of the set, estimates of total weight of each species caught, weight of portions kept (i.e. for subsequent landing), and weight of portions discarded. When practical, observers obtained a random bucketful (25-30 kg) sample of discarded plaice. Length-frequencies (total length to nearest cm) by sex, and proportion of sample weight by sex were recorded. Otoliths, for subsequent ageing, were also collected for one sample on each trip. It was intended that the landings of observed trips would be sampled for length-frequency (by sex) at the time of unloading. Ready access to unloaded fish proved difficult and attention was redirected to obtaining samples of kept fish while still at sea. Quantity of fish landed was obtained, when possible, from the weighout records of the fish plant at which the fish were landed.

To test the consistency and accuracy of captains' estimates of fish quantities, their accumulated estimates of kept catch weight (i.e. of landed weight) of plaice for each trip were compared to weighout quantities at the fish plant for the same trip (Fig. 2). Largest discrepancies from proportionality occurred for some trips with low captains' estimates. This resulted from the plant practice of tallying landings from several trips of a vessel landing small amounts before issuing a purchase record.

Such multiple trip records could not be distinguished by observers. Based on inspection of Fig. 2, it was decided that five trips for which weighout was greater than captain's estimate by a factor of more than five times would be discounted as likely multiple trip weighouts. This discrepancy was judged to be too large to represent a captain's underestimate. Remaining captains' estimates agreed well with plant weighouts with a small tendency to underestimate. This observation, along with the consistency in the discard data among vessels fishing the same grounds at the same time, supports the view that differences in captains' accuracy of estimation is not likely to confound comparisons of discard quantities between areas and seasons. This method assumes that captains were equally accurate at estimating discarded and kept quantities, and thus that estimated proportion discarded was unbiased.

A consistency check was performed on the mean length and mean weight of sampled fish (kept and discarded) by comparing observations for each trip against a power curve fit of mean weight on mean length based on all trips. Observed weights were in the range of about 67%-150% of expected weights with one exception where observed weight was twice that expected. Both the length frequency and mean weight data for this trip were not included in further analyses.

To amalgamate observed discard rates by month for each gear and area, trip data were weighted by catch size on that trip. Even though associations between catch size and discard rate were not generally apparent (see below) this method was adopted, as it weighted data from each trip by its relative contribution to the total catch. To estimate overall discard rate in Div. 4T in 1976, estimates were combined over months as above and then these combined estimates were weighted for each gear and area by their respective landings, and summed. Exceptions were made by weighting discard rate for seiners in G in November separately, as it was different from other months, and by amalgamating area F trawler landings (which were only 14 t) with those of GHJ, as there were no corresponding discard estimates.

Numbers discarded in 1976 were calculated by dividing the estimated total weight discarded by the mean weight of discarded fish in each gear and area category. A second calculation of discard rates by number was conducted on a subset of 14 trips for which kept, as well as discarded, portions of the catch were sampled, and thus for which both total and mean weights of each portion were known. Overall length composition of discards was derived by weighting trip length compositions, summed over months (except for November in the case of seiners in G), for each area and gear type, by estimated numbers discarded.

Inconsistencies in observer sex determinations indicated that these were not reliable. As a substitute, sex ratios at length in research vessel surveys were used to calculate discards by sex. Sex ratios at length were averaged for three surveys and a smooth curve fitted by eye to provide an average sex ratio at length curve. The 1972, 1976, and 1979 surveys were chosen as they encompassed the time period of study. The overall discard length-frequency for Danish seiners and small otter trawlers was then adjusted by the sex ratio at length to obtain discard length-frequencies by sex. Age data by sex from the September 1976 research vessel survey, which were collected at an appropriate time of year and covered the size range of discards well, were used to determine age composition of discards by sex. An overall Div. 4T age-length key for each sex was used in conjunction with the total discard length-frequency for each sex to obtain age compositions.

Discard rates by length and age were derived by comparing the length (age) frequencies of kept fish with those of the total catch to obtain percentage of plaice kept at length (age). The sigmoid curves so derived are called cull ogives in this paper. The 50% cull points were estimated by eye from these curves to the nearest 0.5 cm.

Gear selection was estimated by comparing commercial catch composition in 1976 with composition of the plaice population as estimated by the 1976 research vessel survey. The survey trawl was equipped with small mesh liners of 32 mm in the lengthening piece and of 6 mm in the codend (Halliday and Kohler, 1971). Although mesh selection studies (Clay, 1979) indicate that a 32 mm mesh should retain 50% of plaice of 7 cm in length survey catches had a modal length of 22 cm (see below), indicating that fish smaller than this may not have been fully available to the survey gear. Thus, over the size range of commercial catches, i.e. greater than 20 cm, the survey probably gave an unbiased estimate of population size structure except at the smallest sizes. This method of calculating gear selection requires standardization of the numbers at length in the right hand (fully-selected length groups) portion of the catch length-frequency with those of the population. The ratio of catch to population numbers in the left hand portion of

the catch frequency is then taken as an estimate of selection at length. Different standardization methods can give different results. In this paper the ratios of catch to population at length were inspected to determine the smallest length group at which the ratio (catch: population) was maximal. The catch was then standardized to the population based on the ratio of catch and population summed (in both cases) for all lengths at and above that maximum.

In addition to the MacLaren Atlantic Ltd. study, data were collected in a pilot study earlier in 1976 on four Danish seiner trips. Data were also available from one trip observed aboard a small trawler fishing in Div. 4T and a large trawler fishing for American plaice in Div. 3OP in 1972, and from six trips in Div. 4T in 1979 (five on seiners). Data collection and analysis procedures for these were the same as given above for the larger study.

RESULTS

Quantities of American Plaice Landed

In 1970-79 commercial landings of Div. 4T American plaice averaged 10,000 t annually (Table 2). The amount landed as unspecified flatfish exceeded 2000 t (23% of total) in 1970-71 but declined to less than 1000 t by 1978-79 (7% of total). Landings in the 1970s were quite stable with a low of 8,000 t recorded for 1973 and a high of 12,000 t recorded in 1976. Most landings were by small locally-based vessels. Large trawlers usually landed less than 1000 t of plaice from the area but 1976 was an exception. The peak catch in that year resulted from an unusually high level of participation by large trawlers which had landings of about 4,400 t (37% of total). Otter trawlers longer than 100' were prohibited from fishing for plaice (and cod) in Div. 4T in subsequent years. Trawler landings included a small foreign component, mainly French, but non-Canadian landings exceeded 100 t only in 1975.

In 1976, the year of the main discard study, about 7500 t of plaice were landed by small locally-based vessels. Of that total, about 3000 t (40%) were landed by trawlers, 3400 t (45%) by seiners and 1100 t (15%) by other vessel types such as gillnetters and longliners. Landings from Powles' (1965) southern group (defined for this purpose as landings from unit areas FGHJ) comprised 45% of the total and from his northern group (unit areas KLMNQ) comprised 55%. Landings from the southern group were mainly (70%) by seiners, whereas those from the northern group were primarily (60%) by trawlers. Other gears accounted for about 15% of landings from both areas.

In 1976, large trawler landings were concentrated in April and May (Table 3) and most likely were taken along the eastern edge of the Magdalen Shallows (areas F and K) as the ice receded (and thus came from both northern and southern groups). Small-vessel landings were more evenly distributed over time, with over 1,000 t landed in each month from May to September (Table 3). About 45% of their catch was taken from August to December, the main discard sampling period. Overall, however, almost 50% of the landings occurred in April and May.

Size and Age Composition of Landings in 1976

Of the almost 12,000 t of plaice landed in 1976, males accounted for only about 15% (Table 4). By number, males accounted for about 25% of the 20 million fish landed. The average landed fish weighted 0.6 kg, was 38 cm long and 11 yr old. Landed males were smaller and lighter than females, and about one year younger on average. Fish landed by Danish seiners were slightly smaller and younger than those from small otter trawlers. Fish landed from large trawlers were larger and older than those from small vessels. This is consistent with these landings coming from the edge of the Laurentian Channel in spring where larger fish overwinter (Powles, 1965).

Few fish under 30 cm were landed (Fig. 3). Males contributed significantly to landings only in the 30-40 cm range, while significant numbers of females were taken up to 60 cm. The first age group to contribute significantly to landings was age 7, and few males over age 13 occurred in landings although females up to age 20 were not uncommon.

Population Structure and Trends from Research Vessel Surveys

Research vessel survey biomass estimates for American plaice in Div. 4T increased from about 60,000 t in 1971-72 to a maximum of almost 200,000 t in 1976-77 (Koeller and LeGresley, 1981). There has been a declining trend since the late 1970s (eg. see Matuzals, 1985).

Powles' northern and southern groups (in strata 15-29 and 31-39 respectively) were similar in population characteristics and temporal trends. Increases in survey catches occurred throughout Div. 4T in the later 1970s (Koeller and LeGresley, 1981). Both northern and southern groups increased in abundance in a similar

pattern with the southern group comprising on average about 18% of the total Div. 4T biomass. In 1976, mean age of the populations in strata 15-29 and 31-39 was similar at 6.2 yrs and 5.8 yrs respectively. Ages 3 and 4 were more important in strata 31-39 than in strata 15-29, whereas age 5 was the predominant age group in the latter area (Fig. 4). Length compositions in the two areas were similar, the largest mode in strata 31-39 (at 21 cm) being slightly less than that of 22 cm for strata 15-29 (Fig. 4). Mean lengths at age for the two areas for each sex (Fig. 5) showed ages 4 and 5 fish to be slightly larger in strata 31-39 but differences between sexes were greater than differences between areas after age 6.

Results of 1976 Discard Project (MacLaren Atlantic Ltd.)

In area KLN, both cod and plaice were important contributors to catches and together comprised almost all of the catches of vessels with observers aboard. On eight observed otter trawler trips, an average of 53% (range: 35-80%) of the kept catch of these two species was cod. For Danish seiners plaice was more important, two trips having almost no cod and the remainder having 25-75% (overall mean = 41%, n = 14). Vessels which fished M also had predominantly plaice, cod comprising 15-40% (mean = 28%, n = 4) of the kept catch. Therefore there was a close relationship between cod and plaice fisheries in KLN and M.

Observed otter trawlers in G (n = 6) fished primarily for white hake and sometimes winter flounder. Cod and plaice were relatively unimportant except in one trip when plaice predominated in the kept catch. Danish seiners in G fished plaice almost exclusively. Cod, the second most important species, amounted at most to 30% of the kept catch in observed trips (mean = 15%, n = 10).

Discard rate by weight: For all trips sampled, discard rate was 42% by weight of plaice caught (Table 5). The largest differences in discard rates between areas, gears and months were accounted for by the low discard percentages of Danish seiners in area G in November at an average of 15%. When these data were excluded, the overall discard rate for seiners in G was 47%, higher than that of seiners in KLN (Table 5). Seiners in M had the highest discard rate (62%) but this was based on data from only two trips in October. This estimate was close to that for seiners in the adjacent area KLN in the same month. Overall, there was no clear evidence of major differences in seiner discard rates by area or season, with the exception of area G in November.

Although plaice discard rate for seiners in area G was not related to total plaice catch, it was inversely correlated with catch rate of plaice ($R = -0.64$, $n = 10$). Catch rate was defined as the estimated total plaice catch per hour fished. The low discard rates of seiners in area G in November were related to high plaice catch rates in that month. In KLN, where an inverse correlation between seiner discard rate and total plaice catch was found ($R = -0.60$, $n = 14$), discards and catch rates were also inversely correlated ($R = -0.62$, $n = 13$). The relationship between seiner discard and catch rates for the two areas was different, however. Discards at the same catch rate in area G were about half those in area KLN (Fig. 6).

Trawlers had higher discard rates than seiners except in area M, where data were sparse, and in KLN were slightly higher then in G. There was no relationship between discard rate and catch rate in the case of trawlers.

Amalgamating discard data over gears and areas based on relative landings (Table 6) indicated that locally-based fleets discarded 40% of catches in the southern area and 48% in the northern area for an overall rate of 45% in 1976. Estimated total discard by these fleets was about 6,100 t (Table 6). Vessels using gears other than trawl or seine were assigned a zero discard rate for this calculation. As Powles (1969) pointed out, plaice discarding is not a significant feature of gillnet and longline fisheries.

The unusually high participation of the large trawler fleet in this fishery in 1976 was not anticipated in the discard sampling plan and no data were collected on their discard rates. Their catch was taken mainly in April and May, prior to the discard study being initiated. While culling practices on large trawlers fishing plaice may have been similar to those on locally-based vessels (see below), the size-structure of the population being fished may have been quite different from that fished by local trawlers later in the year. The greater size of fish in large trawler landings (Table 4) supports the view that the population fished had a different size structure. Few fish less than 32 cm in length were landed by large trawlers while small vessels landed significant quantities of fish in the 29-32 cm range. If it is assumed, nonetheless, that large trawler discard rates were the same as those for locally-based trawlers (54%), this implies that a further 5,100 t were discarded for an overall total in 1976 of about 11,200 t (49%).

Discard rate by number: The sum of discards by number for Danish seiners and small otter trawlers was 29.4 million fish. These vessels landed 11.8 million fish (Table 4) and thus discards represented 71% of the 41.2 million fish caught by these components (and 49% by weight - Table 6). On the assumption that gears other than seine and otter trawl had no discards but the same size composition of landings as those by seine and otter trawl, the 45% discard by weight for all small vessels (Table 6) corresponds to 68% by number (13.9 million landed - Table 4).

If large trawlers had the same discard characteristics as small trawlers they would have discarded 24.4 million fish (81%). Total discards in 1976 would have been 53.8 million fish (73%). As pointed out above, however, large trawlers may have fished aggregations of larger fish compared to those fished by small trawlers later in the year. Thus, this total discard rate is likely an overestimate.

There were 14 trips for which numbers kept and discarded could both be calculated; 9 from G, 3 from KLN, and 2 from M; 11 from seiners and 3 from trawlers. For these trips, percentage discarded by number was strongly related to percentage discarded by weight (Fig. 7). On this curve, which was applicable to Danish seiners and small otter trawlers, a discard rate by weight of 49% corresponded to a discard rate by number of 74%, close to the 71% estimated above for these vessels.

Characteristics of discarded fish: Mean length of discarded fish varied between 25 and 33 cm among trips. Mean weight varied between 150 and 370 gm. Primary modes in monthly length - frequency distributions of discards lay between 26 and 30 cm; mean lengths varied between 26 and 31 cm and mean weights between 155 and 290 gm (Fig. 8). Mean lengths and weights of discards were highest in November-December for area G seiners at 30-31 cm and 271-290 gm and area M trawler discards were similar. Length and weight of discards increased over time for each gear in each area, except for trawlers in G. Danish seiner discards in G were larger and heavier than in KLN, whereas area F discards tended to be intermediate. Area M seiner discards were larger than those in other areas in the same month. Otter trawler discards were similar in length between G and KLN but heavier in the latter area, whereas those in M were substantially bigger. The combined length composition of discards by both gears in all areas ranged between 11 and 40 cm, but primarily between 20 and 35 cm, with a mode at 28 cm. Mean length was 27.0 cm and mean weight was 207 gm.

A more detailed comparison of discard size composition between M and KLN can be made for seiners. Both trips in M in October were, in fact, partial trips. The remainder of each trip was fished in KLN with effort being substantial, and evenly distributed between areas (11-15 successful sets in each). The means for these trips were:

	Mean length (cm)		Mean weight (gm)	
	KLN	M	KLN	M
Trip 5	27.6	29.4	189	203
Trip 11	27.6	26.6	232	256
Mean	27.6	28.6	196	217

These data support the view that differences observed in discard characteristics between M and adjacent areas, although not large, were real.

The sex ratio in discards was 61:39 males to females respectively. Length-frequencies for both sexes had modal lengths of 28 cm (Fig. 9) but mean length for males (26.9 cm) was lower than for females (27.3 cm).

Discarded fish ranged in age almost entirely between ages 3 and 12, with a modal age of six, in both sexes (Fig. 9). Males were on average slightly older (6.45 yrs) than females (6.16 yrs), males being particularly predominant at ages 8 and older.

Discard rate by sex: Numbers discarded and landed (Table 4) by sex by Danish seiners and small otter trawlers (in thousands) were as follows:

	Discarded	Landed	Caught	% Discarded
Males	18,012	2,355	20,367	88
Females	11,355	9,481	20,836	54
Total	29,367	11,836	41,203	71
% Males	61	20	49	

Thus, 88% of males were discarded, but only 54% of females. Interestingly, the sex ratio in the catch is almost 1:1.

Discard rate at length and age: The 14 trips used above for calculation of numbers caught and discarded also provided a basis for calculation of the percentage kept at each length. To minimize variability resulting from small sample sizes of kept fish, data were amalgamated by month within area and gear type. Despite the small sample size of kept fish in most cases, plots showed a fairly smooth progression of increase in retention over the 30-40 cm length range (Fig. 10). The 50% cull point could be estimated reliably for all but area G trawlers. In that instance 50% points between 32 and 33 cm

were possible although 32 cm appeared the most likely. Overall, estimates ranged from 31.5 to 35.5 cm (Table 7). There were insufficient data to determine whether there were consistent differences related to area, gear or month. There was no association between the 50% cull point and percentage of discards either by number or weight. There was an indication, however, that 50% cull point and mean length of discards were correlated (assuming trawlers in G had a 50 cull point of 32.0 cm, R = 0.81, p approx. 0.05). Mean length of discards would increase with increase in cull size when the same size composition of fish was being fished, but percentage discard would also increase. There was no evidence of the latter. Thus, the results indicated that cull size was higher when the proportion of small fish in the catch was low and vice versa. A composite ogive based on the sum of all discard and kept length-frequencies of plaice on all 14 trips sampled gave an estimated 50% cull point of 33.0 cm (Fig. 11).

Size compositions of landings estimated from shore samples were compared to size compositions of discards for the same gears and areas to derive other estimates of cull ogives. Length-frequencies of discards and landings were adjusted to represent the tonnages given in Table 6 prior to derivation of cull ogives. Unfortunately, shore samples from small otter trawlers were limited to KLN, restricting otter trawler comparisons to that area. The preponderance of samples were taken in the first part of the fishing season (Table 1), prior to discard sampling, which could have introduced bias in the cull ogives derived.

Cull ogives derived from these calculations gave estimated 50% cull points between 31.3 cm and 32.7 cm except that for Danish seiners in M, which was 35.0 cm (Fig. 12). This latter curve was the most irregular in shape and may be the most unreliable, but the estimated 50% cull point for otter trawlers in this area was also 35.0 cm (Table 7). This could, therefore, have reflected a real difference in culling practice on vessels fishing in M. The 50% cull point for Danish seiners in KLN estimated by both this and the previous method were essentially identical at 31.5 cm, but that for seiners in G, 32.3 cm, was lower using this method. This calculation provided the only estimates for seiners in F, which had a 50% cull point (at 32.7 cm) similar to that for seiners in G. Trawlers in KLN had a 50% cull point (at 31.7 cm) almost the same as that for seiners in the same area.

Comparing total discards at length for seiners and small trawlers in all areas combined with totals landed (Fig. 13) gave an overall 50% cull point of 32.0 cm (plotted on Fig. 11 for comparison with previous estimate). This was in good agreement with the estimated 50% cull point of 33.0 cm based on the composite of 14 discard study trips. The later estimate was more heavily influenced by data from seiners in area G, as no weighting by tonnages landed was involved in its derivation. The cull ogive based on shore samples may, therefore, be the more accurate.

A similar comparison of discards and landings by age for these vessels (Fig. 14) gave a 50% cull point of 8.5 yrs (Fig. 15) for sexes combined. The cull ogive for males was less smooth than for females but it is clear that the 50% cull point was about 10.5 yrs, substantially higher than the 7.5 yrs for females (Fig. 15).

Other Discard Data Collected in the 1970s

Other 1976 data: Four Danish seiner trips which originated from northern New Brunswick ports were observed between 20 May and 1 July 1976. Area fished was not available but was most likely KLN. Discards by weight ranged from 44 to 56% with a mean of 49%. Kept portions of catches were not sampled, thus discard percentage by number could not be calculated. Length-frequency of discards had a modal length of 27-28 cm, a mean of 26.7 cm, and most discards lay within the range 20-32 cm. Mean discard weight was about 0.15 kg.

These late May and June data indicated that discarding practices in the early part of the fishing season were similar to the later part, at least for Danish seiners in KLN. Length - frequencies of KLN seiner discards in the two sampling periods May-July and August-October (Fig. 16) were similar. Mean length of discards was almost identical at 26.7 and 26.9 cm respectively although mean weight was higher in August-October (0.20 kg). Discard percentages by weight were more variable in August-October (9-72%) and the mean was lower at 42% (Table 5). Cull ogives calculated for each period, using shore samples to obtain landings length - frequencies for each period separately, were similar and the 50% cull points were almost identical at 31.5 and 31.3 cm for earlier and later periods respectively (Fig. 12).

Data collected in 1972 - small trawler: A single trip of a northern New Brunswick otter trawler which fished in area KLN was sampled in October 1972. Estimated discards were 26 and 40% of total plaice catch by weight and number respectively. Discards ranged mainly between 24 and 32 cm, with a mode at 28 cm and a mean of 27.9 cm (Fig. 17). Estimated 50% cull point was

30 cm (Fig. 17).

Length-frequency of kept fish was estimated from a shore sample subsequent to landing, but the sample weight was not obtained. Neither was the mean weight of discarded fish estimated. To scale the length-frequencies of sampled discards and landings to the estimated total weights discarded and kept during the trip, a length-weight relationship for Div. 4T plaice obtained in October 1959 (Kohler et al., 1970) was used to calculate mean weights of fish discarded and landed from the appropriate length frequencies. This allowed the calculations which gave the above results.

A comparison of these data with those from small trawlers in KLN in 1976 follows:

	Oct. 1972	Oct-Nov 1976
Discards by weight	26%	56%
Discards by number	40%	76%
Mean length in discards	27.9 cm	26.6 cm
Mean length in landings	34.0 cm	37.9 cm
50% cull point	30.0 cm	31.7 cm

Both the 50% cull point and mean length of landed fish were lower in 1972 than in 1976. If the population being fished had the same size composition in the two years, the lower 50% cull point in 1972 would result in lower discard rates and a smaller mean length of discards in that year. Discard rates in 1972 were lower, consistant with this expectation. Mean discard lengths were higher in 1972, however, suggesting that the lower discard rate was a result of relatively fewer small fish occurring in the catch, as well as of the lower cull point.

Data collected in 1972 - large trawler: Although there were no data on plaice discarding practices by large otter trawlers when fishing in Div. 4T, one fishing trip was observed aboard a Nova Scotia-based vessel of this class which fished for plaice primarily on Green Bank (Div. 3OP) in November 1972. Percentages of plaice discarded by weight and numbers were only 4% and 15% respectively but the characteristics of discarded plaice were similar to those discarded by the small trawler sampled in Div. 4T in 1972. Discards were mainly composed of fish of 23-33 cm with a modal length of 29 cm and a mean length of 28.2 cm. The estimated 50% cull point was 30.5 cm (Fig. 17) which was also similar to that of the small trawler. Thus the large difference in the proportion of the catch discarded did not stem from a difference in discarding practice aboard the two vessels but from a difference in catch size-composition, that of the large trawler having a greater proportion of large fish.

Data collected in 1979: Discard rates were observed on six trips in 1979, all in KLN. On one otter trawler trip in June, discard by weight amounted to 29% of plaice caught. In October a Danish seiner also had a discard rate of 29% by weight. In July-August four trips, all aboard the same Danish seiner, had discard rates of 28-35%, averaging 32%. The discarded and kept portions of the catches on these latter trips were sampled to obtain estimates of numbers discarded and the length-frequencies of each portion. Discards by number were 45-54% with a weighted average of 52%. These ranged in length mainly between 22 and 35 cm, with a mode at 30 cm and a mean of 29.1 cm. Estimated 50% cull point was 33cm (Fig. 17).

A comparison of these July-August data with those from Danish seiners in KLN in 1976 follows:

	July - Aug. 1979	Aug. - Oct. 1976
Discards by weight	32%	42%
Discards by number	52%	65%
Mean length in discards	29.1 cm	26.9 cm
Mean length in landings	37.3 cm	36.4 cm
50% cull point	33.0 cm	31.5 cm

Both the 50% cull point and mean length of fish in landings were higher in 1979 than in 1976. The higher mean length of discarded fish in 1979 is also consistent with the higher cull point. The lower discard rate in 1979, however, suggests that there were relatively fewer small fish in the 1979 catch compared to 1976, and the larger mean length of discards was likely a function of this as well as of the higher cull point.

Gear Selection

The proportion of the population at length which is caught by fishing gear is a function of mesh size used (in the case of otter trawls and seine nets) and of the size composition of the sector of the population fished, e.g. whether the fishery is prosecuted in areas where large or small fish concentrate. The calculation used here, which compared 1976 catch length composition with population length composition estimated from the 1976 survey, gave an estimate of overall gear (but not mesh) selection.

The gear selection ogive for the small vessel fishery (small otter trawlers and Danish seiners combined) in 1976 (Fig. 18) had a 50% selection point of about 25 cm. (The actual data points suggested a slightly lower 50% point, but a smoothed ogive gave 25 cm.) The same

calculation for otter trawlers and Danish seiners separately gave 50% selection points of about 24.5 cm and 25.5 cm (when smoothed) respectively (Fig. 18). The otter trawler ogive was steeper than that for seiners. As pointed out in Materials and Methods, the precise numbers obtained depend on exactly how the catch and population curves are standardized. The results do indicate, however, that there was likely a difference in gear selection between trawlers and seiners.

DISCUSSION

In his study of discarding by northern New Brunswick otter trawlers, Jean (1963) pointed out that the characteristics of discards varied as a function of mesh size, population size-structure, and culling practices aboard the vessels. The mesh selection ogive determines the proportion at each length, of fish available to the gear, which will be retained as catch. The cull ogive imposed by the vessel crew determines the proportion of fish at each length in the catch which are retained for subsequent landing. Generally, the greater the proportion of the fished sizes in the population in the size range between selection and cull ogives, the greater the proportion of discarded catch.

Mesh size: Mesh size regulations were first introduced into the southern Gulf of St. Lawrence groundfish fishery in 1957. The ICNAF regulation requiring member countries to introduce a 114 mm (4.5 in) minimum codend mesh size for otter trawls in Subarea 4 (of which Div. 4T is a part) came into force in November 1957, but Canadian domestic regulations (which provided the legal basis to enforce the ICNAF regulation on Canadian fishermen) became effective prior to that, in February 1957. This new mesh size was phased into use in the southern Gulf of St. Lawrence groundfish fishery during 1957 and 1958 and it was 1959 before all otter trawlers were equipped with it (Jean, 1963). This example demonstrates that the timing of practical implementation of a regulation does not necessarily correspond to the time when the regulation becomes a binding international obligation or becomes effective under Canadian law. Granting of "grace periods" is entirely at the discretion of DFO. The 1957 mesh regulations applied only when fishing for cod and haddock and not American plaice, but as cod was the primary groundfish fished in Div. 4T by trawlers, all converted to the new mesh size.

Prior to the introduction of mesh size regulation, otter trawlers commonly used a mesh size of about 75 mm (Jean, 1963). Neither Jean (1963) nor Powles (1969) mention the mesh size used by Danish seiners, which were just being introduced into the southern Gulf fishery at the time trawlers became subject to mesh regulation, but probably it was similar to that used by otter trawlers prior to regulation. Jean (1960) notes a seiner from Cheticamp using about 90 mm (3.5 in) mesh in 1959. It was not until December 1967 that the ICNAF regulations (October 1968 in the case of Canadian regulations) were extended to include seine nets. These same amendments introduced American plaice as a regulated species, and first specified differentials in mesh sizes dependent on construction material (or gear in the case of seines). While the standard mesh size remained 114 mm, trawl nets of cotton, hemp, polyamide and polyester could have meshes of 105 mm and seine nets could have 100 mm meshes. Powles (1969) records that all vessels (presumably he meant trawlers) had switched to 114 mm synthetic codends by 1960, so the introduction of differentials may have allowed for some reduction in mesh size depending on the synthetic used.

A further amendment to the ICNAF regulations which increased the minimum mesh size to 130 mm manila equivalent (seine nets - 110 mm, trawls of cotton, hemp, polyamide and polyester - 120 mm) became effective in January 1974 (February 1974 in the case of Canadian regulations). Canadian regulations were changed again in September 1981 to eliminate differentials, and this effected an increase in minimum mesh size for seine nets from 110 to 130 mm, as well as standardizing all trawl nets at 130 mm.

It has not been possible to locate records describing the practical implementation (enforcement) of mesh size changes, or data on mesh size in use, subsequent to the initial imposition of mesh regulations described by Jean (1963). During the period of the present study (1972-79), seine nets should have had a minimum mesh size of 100 mm through 1973 and 110 mm from 1974, and otter trawlers should have had 114 mm and 130 mm (manila equivalent) codends respectively for these periods. The otter trawler sampled in 1972 was recorded as using a polyamide codend of 114 mm. In 1976, data were not collected on mesh size used on observed vessels but the nets of 8 vessels (4 seiners and 4 trawlers) measured at Caraquet wharf by MacLaren observers had average codend mesh sizes of 112 mm for seiners and 131 mm for trawlers. No records of mesh size were taken with the 1979 discard samples. These scant records indicate that mesh sizes in use approximated the legal minimum.

Gear selection ogives for 1976 (Fig. 18) indicate 50% selection occurred at 24.5 cm for

otter trawlers and 25.5 cm for Danish seiners. According to Clay's (1979) general mesh selection pattern for American plaice, a regulation otter trawl mesh size of 120 mm (synthetic) corresponds to a 50% mesh selection length of 27.5 cm, higher than that observed. The observed values correspond closely to what might be expected if 105 mm (synthetic) mesh for otter trawls were still in effect (i.e. 24.0 cm), as would be the case if the grace period for the introduction of the 1974 changes extended through 1976. In any case, a comparison such as this cannot be conclusive as the behaviour of the vessels, as well as the mesh size, affects gear selection as calculated here. Vessels fishing mainly in areas with high proportions of small plaice (i.e. plaice within the mesh selection range) would have given a lower estimated 50% gear selection length than would vessels concentrating in areas where plaice were larger, even if the same mesh size was used. In 1976, catch compositions of observed otter trawlers indicate that cod was an important, and sometimes the primary, species caught whereas for seiners plaice predominated. It can be speculated that plaice caught largely incidentally to cod were smaller than those toward which seiners directed their effort.

Comparison between observed gear selection and expected selections based on mesh size is complicated by the lack of knowledge concerning Danish seine mesh selection for American plaice. The original basis for a seine net differential was unsound (McCracken, unpublished[1]). There is, therefore, no basis to expect that a Danish seiner and an otter trawler fishing with, say, 110 mm and 130 mm mesh nets respectively, but otherwise identically, would exhibit the same selection at length.

Culling practices: Jean (1963) provided no data on culling practices at length, and Powles (1969) provided some only indirectly. Powles concluded that all fish 31 cm and less were discarded and all fish 36 cm and larger were kept (except by otter trawlers in area N where the latter value was 34 cm). To calculate discard rates, Powles (1969, figure 14) approximated the left-hand limb of the length-frequency of kept fish by a straight line joining these extreme values. (This implies a variably shaped cull ogive depending on the length-frequency of the catch in the cull range.) Interpreting Powles' (1969) figure 14 by eye indicates 50% cull points in the range 33-35 cm in 1959-61. These can be considered only rough approximations, however.

In 1976, culling practice was more closely related to area fished than gear used. Estimates of 50% cull point for vessels fishing KLN were between 31 and 32 cm irrespective of gear, whereas estimates for other areas were between 32 and 33.5 cm. Area M estimates were among the highest at 35 cm both for otter trawlers and seiners. The 1972 estimate for the trawler in KLN of 30 cm and the 1979 estimate for the Danish seiner in this same area of 33 cm suggest an increase in the 50% cull point through the 1970s, but the 1972 data were scant. The 1979 data, although more voluminous than those for 1972, were derived from only one vessel. It is clear, however, that Powles' (1969) data, no matter how his figure 14 is interpreted, must give a 50% cull point higher than those of 1972 and 1976. Furthermore, the 1976 data indicate that estimated 50% cull point can vary by as much as 2.5 cm between months for the same area and gear type (Table 7). It must be concluded, therefore, that there are insufficient data to establish temporal trends in culling practice. The apparent association between culling practice and area fished was probably a reflection of differences in acceptability of small fish at different ports, as vessels tended to fish in areas adjacent to their port of landing.

Discard rates: Jean (1963) found that, despite the increase in otter trawl mesh size required by regulation in 1957-59, plaice discards by small otter trawlers actually increased between 1956 and 1961. He attributed this to an increased abundance of small fish which masked the changes resulting from mesh size increase. Jean's (1963) estimates of percentage discard by weight based on observers' logbook estimates increased from about 16% in 1956-58 to about 50% by 1961. However, estimates for 1957-59 based on other methods were higher (34-64%). Jean attributes the difference to underestimation on the part of observers, who obtained their estimates in consultation with vessel captains. This is a plausible explanation, as he compared estimated discards with actual weighouts of landings. Thus, only discard weights were subject to the tendency of captains to underestimate (Fig. 2). Jean's higher estimates were likely the more accurate, therefore. Powles (1969) estimated discards of 31-57% by weight and 54-85% by number for small otter trawlers in 1959-61, but only 15-21% by weight and 43-49% by number for Danish seiners. The highest value, 57% by weight, was for otter trawlers in area N and the lowest, 15% for seiners in area G in November. McCracken (1964) reported that, in summer 1963, two trawlers from New Brunswick and Quebec discarded 25% by weight (50-53% by number) of their plaice catch. They probably fished KLN,

[1] McCracken, F.D. MS 1977. Minimum mesh size review. Unpublished contractor's report to the Department of Fisheries and Oceans, Canada.

but this is not stated. A Danish seiner from Cheticamp (probably fishing area G) discarded 15% by weight (32% by number). In summer 1964 (McCracken et al., 1965), two small trawlers fishing KLN discarded only 4% and 8% of their catches by weight (15-28% by number).

Discards from one small trawler fishing in KLN in 1972, were 26% by weight and 40% by number, comparable to trawlers in 1963 (McCracken, 1964). By 1976, small otter trawlers were discarding 54% of their plaice catch in Div. 4T by weight (76% by number), while Danish seiners were discarding 43% by weight (66% by number). By 1979, discard rates had declined again, with two seiners and a trawler having discards of about 30% by weight (52% by number for seiners).

While the data are scant, there appears to have been a substantial decline in quantities discarded in the mid-1960s which can be attributed to a decline in the proportion of small fish in the population, as there is no evidence of substantial changes in mesh or cull sizes. Discard rates were moderate in 1972 but increased by 1976. This increase corresponded to an increased stock size which peaked in 1976-77. The 1970 year-class and several subsequent ones were substantially stronger than those which preceded them (Metuzals, 1985). These year-classes made their greatest contribution to discards in 1976-77, in the age range 5 to 7 (Fig. 14). By 1979, they had nearly passed through the discard age groups. Thus, the size structure of the fished population had a more discernable effect on quantities discarded than either gear selection or culling practices.

Discard rates of small otter trawlers and Danish seiners differed by about 10% in 1976, trawlers discarding more (54% by weight, 76% by number) than seiners (43% by weight, 66% by number). This confirms Powles' (1969) tentative conclusions. Danish seiner discards tended to be longer and heavier than those of otter trawlers (Fig. 8). To calculate the potential impact of the apparently slight differences in gear selection between the two vessel categories, the 1976 research vessel estimate of population length composition was adjusted by the respective gear selection ogives for otter trawlers and Danish seiners to generate catch length-frequencies for each vessel category. These catch length-frequencies were then adjusted by the same cull ogive (based on shore samples - Fig. 11) to obtain frequencies for discards and landings. The characteristics of discards for the two gears were:

	Otter Trawlers	Danish Seiners
Discards by weight	52%	47%
Discards by number	74%	68%
Mean weight of discards	181 gm	195 gm
Mean length of discards	26.9 cm	27.6 cm

Although cull ogives did not differ between gears in the same area (and thus the same ogive was used for both in the above calculation), they did differ between areas. Most fishing by Danish seiners occurred in area GHJ, where the 50% cull point was higher than in KLN where most otter trawler fishing occurred. Therefore, the overall cull ogive for seiners in Div. 4T would be expected to be higher than that for trawlers. This would reduce the differences in quantities discarded between the two gears as calculated above, but increase the differences in means of length and weight of discards. Even as calculated, the differences in quantities discarded are only 5-6% rather than the 10% observed from empirical data. Thus the full difference in discards has not been accounted for by the calculated difference in gear selection. It must be kept in mind, however, that the calculations of gear selection are only likely to give crude approximations, and a difference in gear selection remains the most likely explanation of the differences between trawler and seiner discards.

The 1976 discard study apparently coincided with the peak of discarding problems in the Div. 4T American plaice fishery in recent years. A similar cycle appears to have occurred almost 20 yrs earlier and was observed at its peak by Jean (1963) and Powles (1969). The declining trend in plaice abundance, combined with the increase in effective mesh size (to 130 mm irrespective of materials) in the early 1980s, should have decreased discard rates substantially. The 50% selection length for 130 mm mesh is about 30 cm for plaice, still below the 50% cull point of 32 cm observed for 1976, so complete elimination of discards could not be expected. Most recent data conflict with expectations, however. Cliche and Côté (1984) report that discards of Quebec trawlers fishing area KLN in 1980 and 1981 were 25% and 40% by weight respectively, but these observations were made before the most recent mesh size increase. However, Chouinard and Metuzals (1985) report discard rates of 40% by weight for various areas in Div. 4T in 1984. This appears to have resulted from a change in culling practices: the 50% cull point in 1984 calculated by Chouinard and Metuzals was 34 cm. Also the data of Cliche and Côté indicate a 50%

cull point of about 34 cm in 1980 and 1981. Thus, the suggestion in the 1970s data that there was an increase in the 50% cull point may, in fact, reflect a real temporal trend. Alternatively, this early 1980's increase in cull size may reflect a tendency for cull size to vary inversely with the proportion of small fish in the catch, as observed in 1976 data.

Comparisons with discard rates in other fisheries: Discard rates in the Div. 4T American plaice fishery in the 1970s and early 1980s, which apparently ranged between 25 and 50% by weight, were higher than in other northwestern Atlantic directed plaice fisheries. Beizile (1978) reported plaice discards of 9% by weight from a large Nova Scotia-based otter trawler fishing plaice in Div. 4V in 1978, and a discard rate of 4% was reported above for a large Nova Scotia trawler fishing for plaice in Div. 3OP in 1972. Newfoundland-based large trawlers have been reported upon more extensively. In the relatively small plaice fishery in Subarea 2 and Div. 3K, discards by weight in 1981-85 were 1-45% (Kulka, 1986), but the highest value was greatly influenced by discards in the cod-directed fishery. In Subdiv. 3Ps, discards were 2-13% in these same years. In the large Grand Bank (Div. 3LNO) fishery discards were 4-6% in 1981-85, but Stevenson (1983) reported higher discards by weight of 8-14% for 1978-82 (20-31% by number). These differences in discard rates between Div. 4T and other areas did not result from differences in culling practices (Stevenson, 1983). The possibility cannot be discounted that they result from differences in distribution, or other aspects of the biology, of plaice among areas. However, the explanation is more likely to lie in differences in mobility and economics of small-vessel and large-vessel fleets, which predominated in the plaice fisheries of Div. 4T and of the outer banks respectively.

Unlike the Southern Gulf of St. Lawrence, the outer shelf has supported groundfish fisheries in which plaice was an incidental, and often unwanted, catch. The traditional fisheries of France, Portugal, and Spain kept only cod, and while the quantities of plaice discarded are not known, it is thought that they were sufficient to have a major adverse impact on directed-fishery yields (Pitt, 1975). These cod fisheries have been greatly curtailed since extension of jurisdiction in 1977. Canadian trawlers prosecuting gadoid fisheries have also discarded most or all of the plaice caught, but the absolute amounts have been negligible in observed cases (unpublished data for two trawlers fishing Div. 4WX and 5Z in 1972; Beizile (1978) for two trawlers in the same areas in 1978; Kulka (1986) for various trawlers in Subareas 2 and 3 in 1981-85).

ACKNOWLEDGEMENTS

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Table 1. Summary of commercial samples of American plaice landings by unit areas of Div. 4T and gear type in 1976 and associated landings (t). Number of samples is followed by number of fish measured/ number of otoliths read, in parentheses. (Two additional samples, one from a longliner fishing in F and one from a seiner fishing in an unknown unit area, not used.)

		Vessel Type		
Area		Danish Seiners	Otter Trawlers (TC 1-3)	Otter Trawlers (TC 4+)
GHJ	Samples	May - 1 (200/39) July - 1 (200/34)		
	Landings	1758	638	...
F	Samples	June - 2 (400/82) July - 1 (200/43) Aug. - 1 (200/35)		
	Landings	629	14	...
KLNOQ	Samples	May - 2 (400/77) June - 10 (2000/361) July - 2 (400/73) Aug. - 6 (1266/236) Oct. - 1 (200/34)	May - 7 (1400/280) June - 1 (200/35)	
	Landings	971	2278	...
M	Samples	May - 1 (200/29) July - 1 (200/36) Aug. - 1 (200/38) Sept. - 1 (200/34)		
	Landings	26	114	...
4T	Samples			April - 2 (404/114) May - 4 (778/155)
	Landings			4366

Table 2. Landings (t) of Div. 4T American plaice, 1970-79.

Year	Recorded as: American plaice	Recorded as: Flatfish not specified[1]	Estimated Total	Caught by: Otter trawlers TC4+	Caught by: Other Vessels
1970	7582	2094	9676	915	8761
1971	7627	2472	10099	1017	9082
1972	8294	1081	9374	1502	7872
1973	6905	1249	8154	864	7290
1974	8485	542	9027	837	8190
1975	8443	2218	10661	720	9941
1976	11193	601	11794	4366	7428
1977	9230	1047	10277	67	10210
1978	9031	688	9719	58	9661
1979	9996	757	10753	376	10377

[1] 90% of "flatfish - not specified" landings assumed to be plaice.

Table 3. Monthly distribution of Div. 4T American plaice landings (t) in 1976 by large otter trawlers and other vessels. (Landings include 90% of "flatfish - not specified" landings.)

Month	Large Trawlers (TC 4+)	Other Vessels	Total
January	10	3	13
February	4	5	9
March	12	4	16
April	1998	111	2109
May	2246	1261	3507
June	5	1642	1647
July	-	1146	1146
August	-	1120	1120
September	-	1157	1157
October	15	606	621
November	64	302	366
December	12	69	81
TOTAL	4366	7426	11792

Table 4. Characteristics of landings of American plaice from Div. 4T in 1976 by gear/vessel type.

Gear/Vessel Type	Numbers Landed ($\times 10^{-3}$)			Weight Landed (t)			Mean Weight (kg)			Mean Length (cm)			Mean Age (yrs)		
	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total	Males	Females	Total
Danish seiners	1568	5002	6570	515	2869	3384	0.33	0.57	0.51	33.0	37.8	36.7	9.0	10.3	10.0
Otter trawlers (TC 1-3)	787	4479	5266	266	2688	2954	0.34	0.60	0.56	33.5	38.7	37.9	9.9	11.1	10.9
All small vessels[1]	2769	11146	13915	918	6533	7451	0.33	0.58	0.53	33.2	38.2	37.2	9.3	10.7	10.4
Otter trawlers (TC 4+)	1683	4119	5802	741	3625	4366	0.44	0.88	0.75	36.4	43.4	41.4	11.0	13.6	12.9
All vessels	4452	15265	19717	1659	10158	11817	0.37	0.66	0.59	34.4	39.6	38.4	10.0	11.5	11.1

[1] All vessels less than 150 grt - numbers and weights landed adjusted by 1.176 to account for landings by gears other than Danish seine and otter trawl.

Table 5. Percentage discard (by weight) of American plaice in Div. 4T by gear, area, and month in 1976. Number of trips observed is in parenthesis (DS = Danish seine, OT = otter trawl).

	Area										
	G		KLN		M		F		All Areas		
Month	DS	OT	DS	OT	DS	OT	DS	OT	DS	OT	Combined
Aug.	34(1)	-	72(2)	-	-	-	26(2)	-	37	-	37
Sept.	-	51(4)	34(7)	-	-	50(2)	51(2)	-	35	50	38
Oct.	49(3)	37(2)	59(5)	41(3)	62(2)	-	-	-	58	39	56
Nov.	15(5)	-	-	57(5)	-	-	-	-	15	57	34
Dec.	43(1)	-	-	-	-	-	-	-	43	-	43
All	23	47	42	56	62	50	38	-	39	53	42
All mo. Gears combined	27		45		57		38				

Table 6. Estimated total discards (t and % of catch) of American plaice in Div. 4T in 1976 (DS = Danish seine, OT = otter trawl).

Area	Vessel Category	Landings (t)	Discards t	Discards %	Catch (t)
Southern					
GHJ	DS (excl. Nov.)	1578	1399	47	2977
	DS (Nov.)	180	32	15	212
F	DS	629	386	38	1015
FGHJ	OT (TC 1-3)	562	498	47	1060
	Other	467	-	-	467
	Subtotal	3416	2315	40	5731
Northern					
KLNOQ	DS	971	703	42	1674
	OT (TC 1-3)	2278	2899	56	5177
M	DS	26	42	62	68
	OT (TC 1-3)	114	114	50	228
MKLNOQ	Other	646	-	-	646
	Subtotal	4035	3758	48	7793
4T	All small vessels	7451	6073	45	13524
	OT (TC 4+)	4366	5125	54[1]	9491
	All vessels	11817	11198	49	23015

[1] Overall discard rate for OT (TC 1-3) vessels.

Table 7. Estimated 50% cull points, discard mean length and percentage of catch by number and weight, by area, gear, and month, for American plaice in Div. 4T in 1976, with summary statistics on sample sizes, for trips on which both discarded and kept portions of catch were sampled.

Area	Gear	Month	No. of Trips Sampled	No. Measured from Catch		50% Cull Point	Discards		
				Discarded	Kept		Mean Length cm	% by Number	% by Weight
G	DS	Oct.	2	1441	63	34.0	27.7	78	50
		Nov.	5	1836	164	33.0	30.1	31	15
		Dec.	1	50	31	35.5	31.0	65	43
	OT	Sept.	1	438	39	32-33	26.8	79	65
KLN	DS	Sept.	3	5186	95	31.5	27.0	54	30
M	OT	Sept.	2	873	73	35.0	30.5	72	50
All	All	All	14	9824	465	33.0			

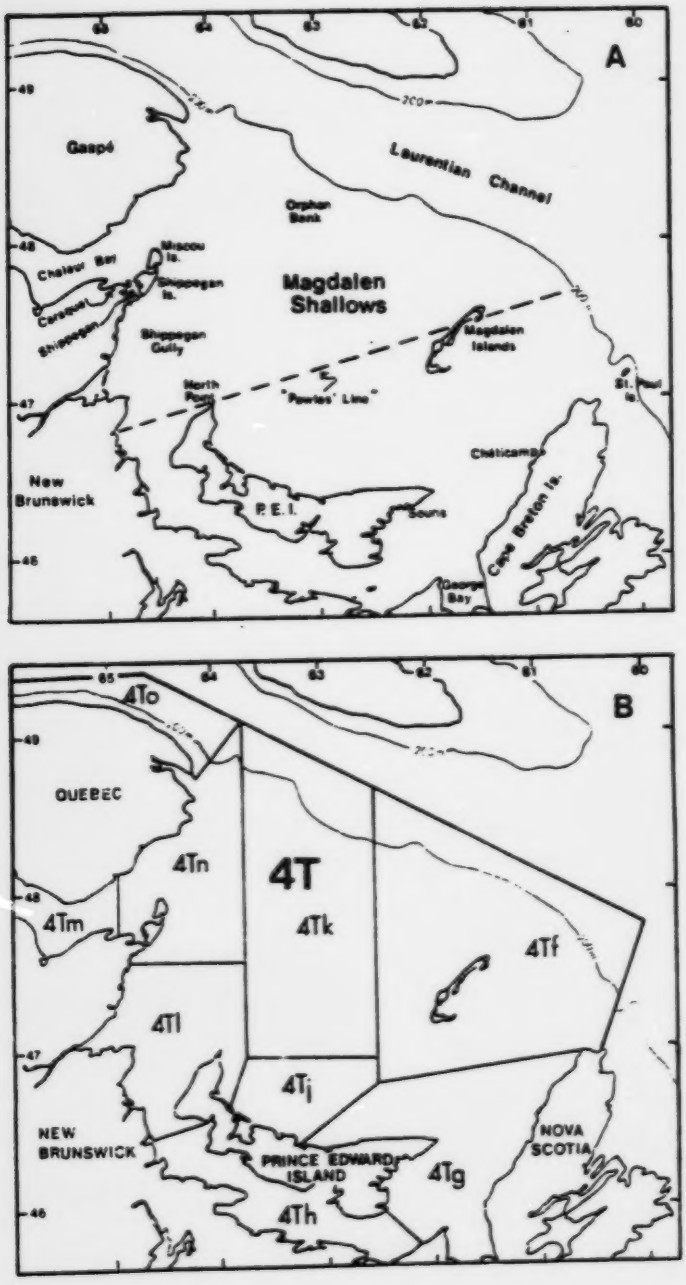

Fig. 1. The Southern Gulf of St. Lawrence, NAFO Div. 4T: A. place names in the Magdalen Shallows area mentioned in the text and approximation of Powles' (1965) dividing line between American plaice groups and B. Canadian statistical unit areas in Div. 4T. (Unit area Q north of Gaspe not shown.)

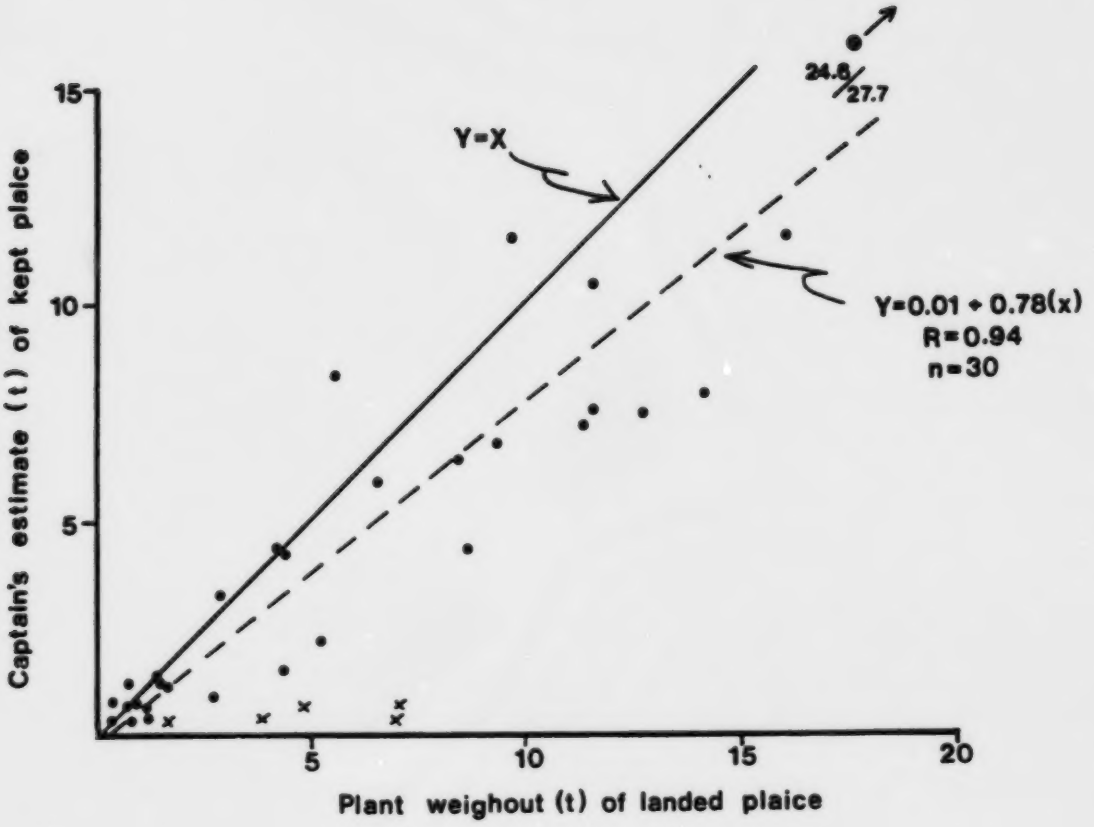

Fig. 2. Relationship between captians' estimates of kept American plaice and plant weighouts of landed plaice by trip. (x - points not used in regression, see text. Regression line dashed, proportional line solid.)

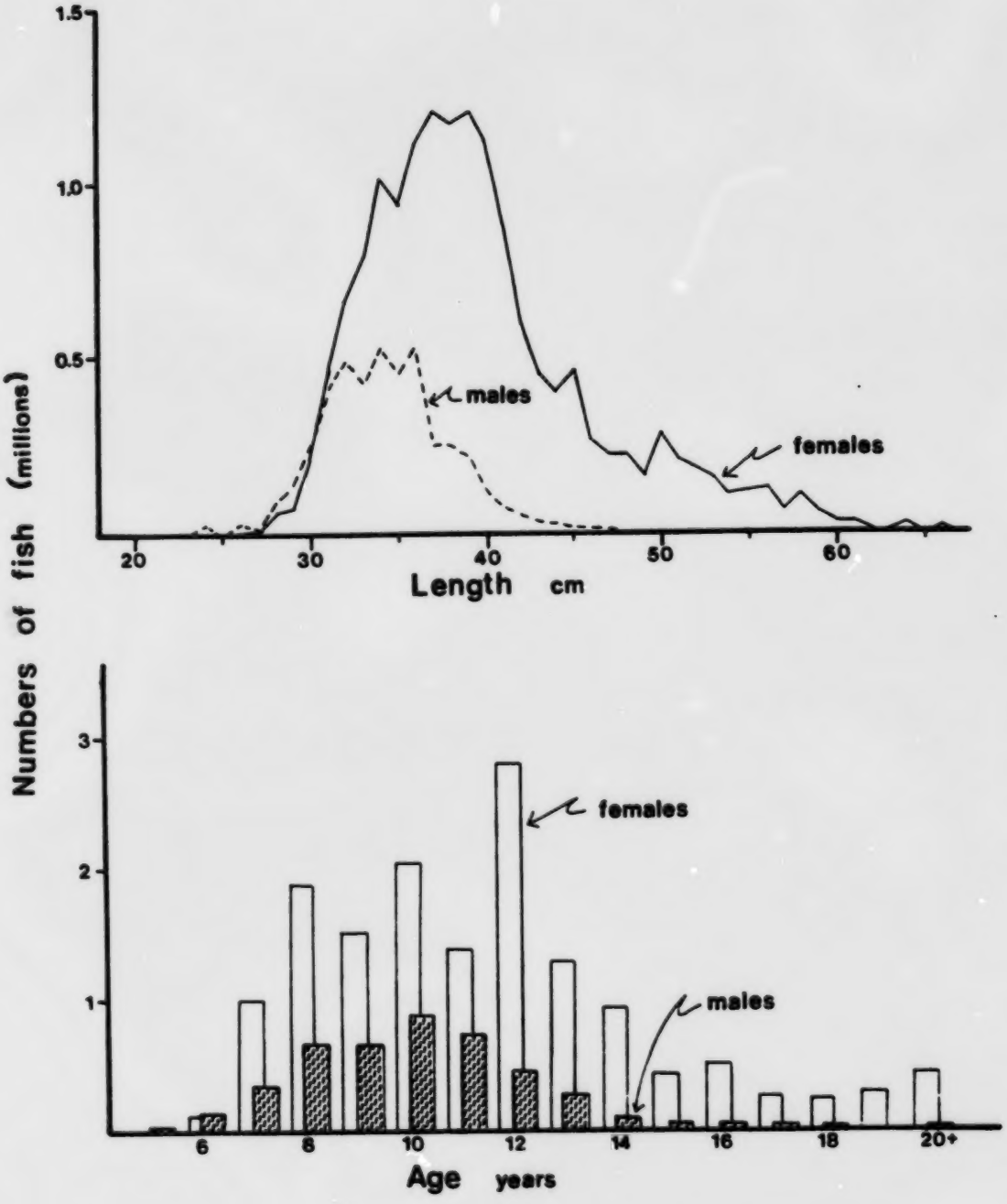

Fig. 3. Length and age compositions of American plaice landings from Div. 4T in 1976 by sex.

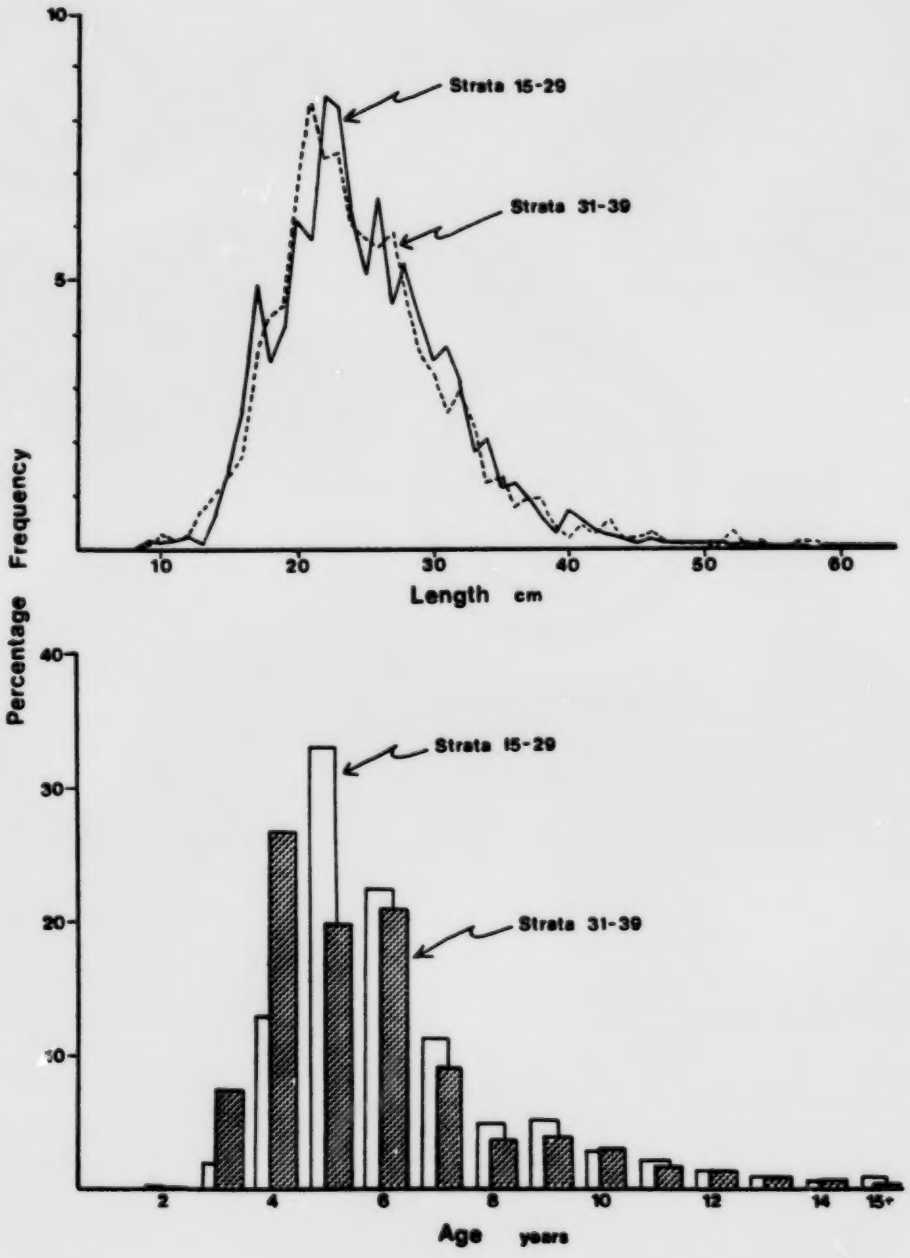

Fig. 4. Percentage frequencies by length and age of the American plaice population in strata 15-29 and 31-39 of Div. 4T estimated from a stratified-random research vessel survey conducted in September 1976.

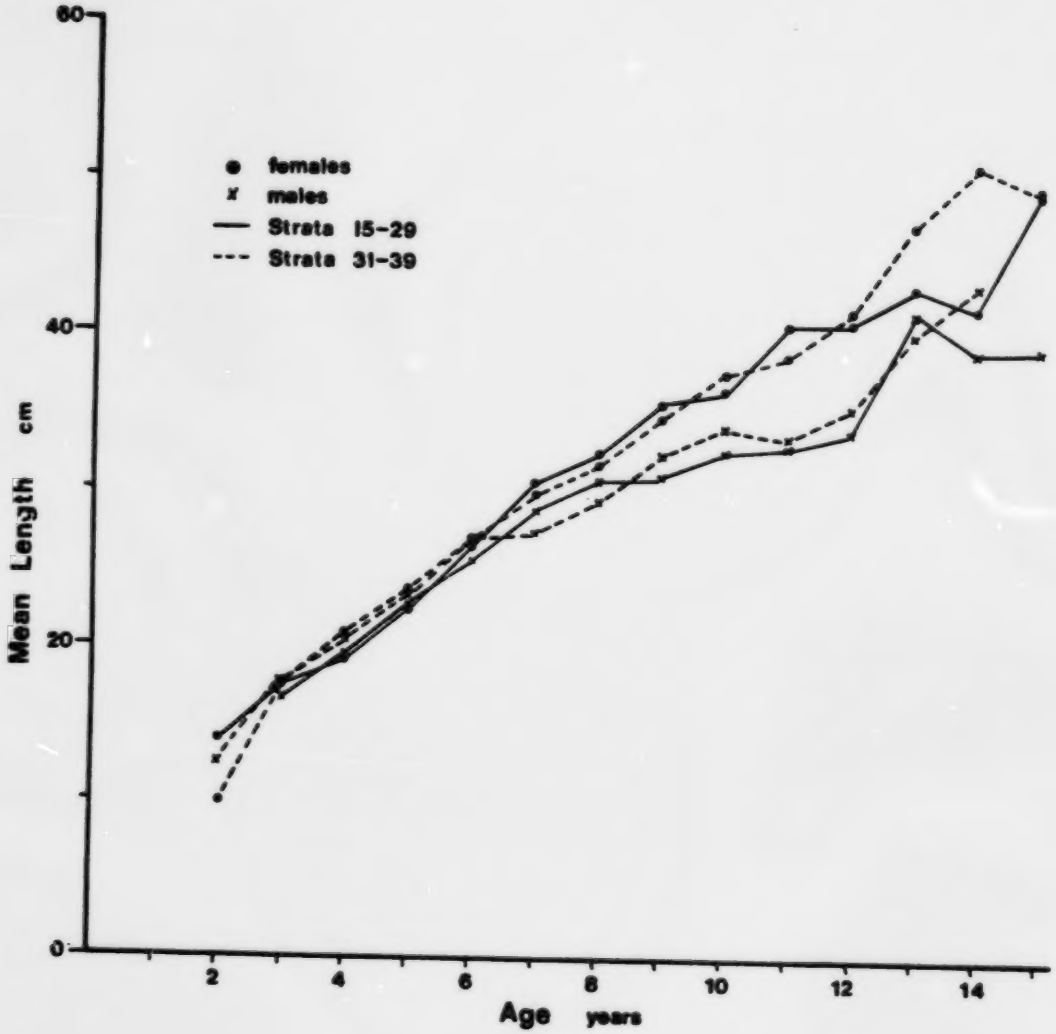

Fig. 5. Mean length at age of male and female American plaice in strata 15-29 and 31-39 of Div. 4T based on data from a stratified-random research vessel survey conducted in September 1976.

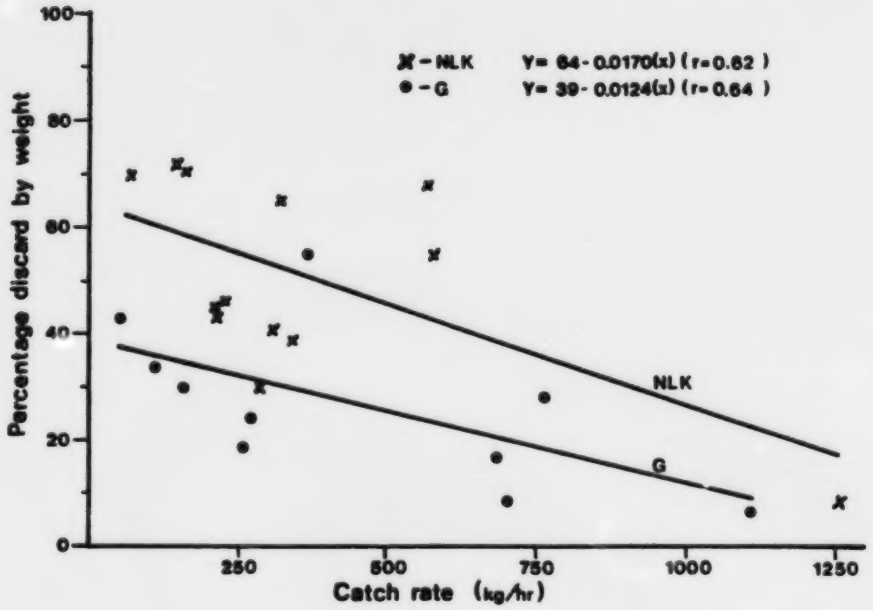

Fig. 6. Percentage discard by weight of American plaice in relation to catch rate of plaice, for Danish seiners in areas NLK and G. (Catch rates are based on estimated plaice catch before discards.)

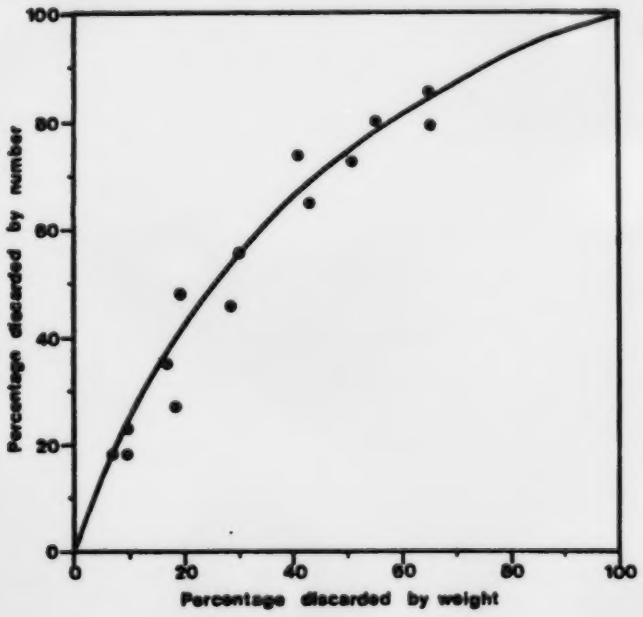

Fig. 7. Relationship between weight and numbers of American plaice discarded per trip in Div. 4T in 1976. (Curve is fitted by eye.)

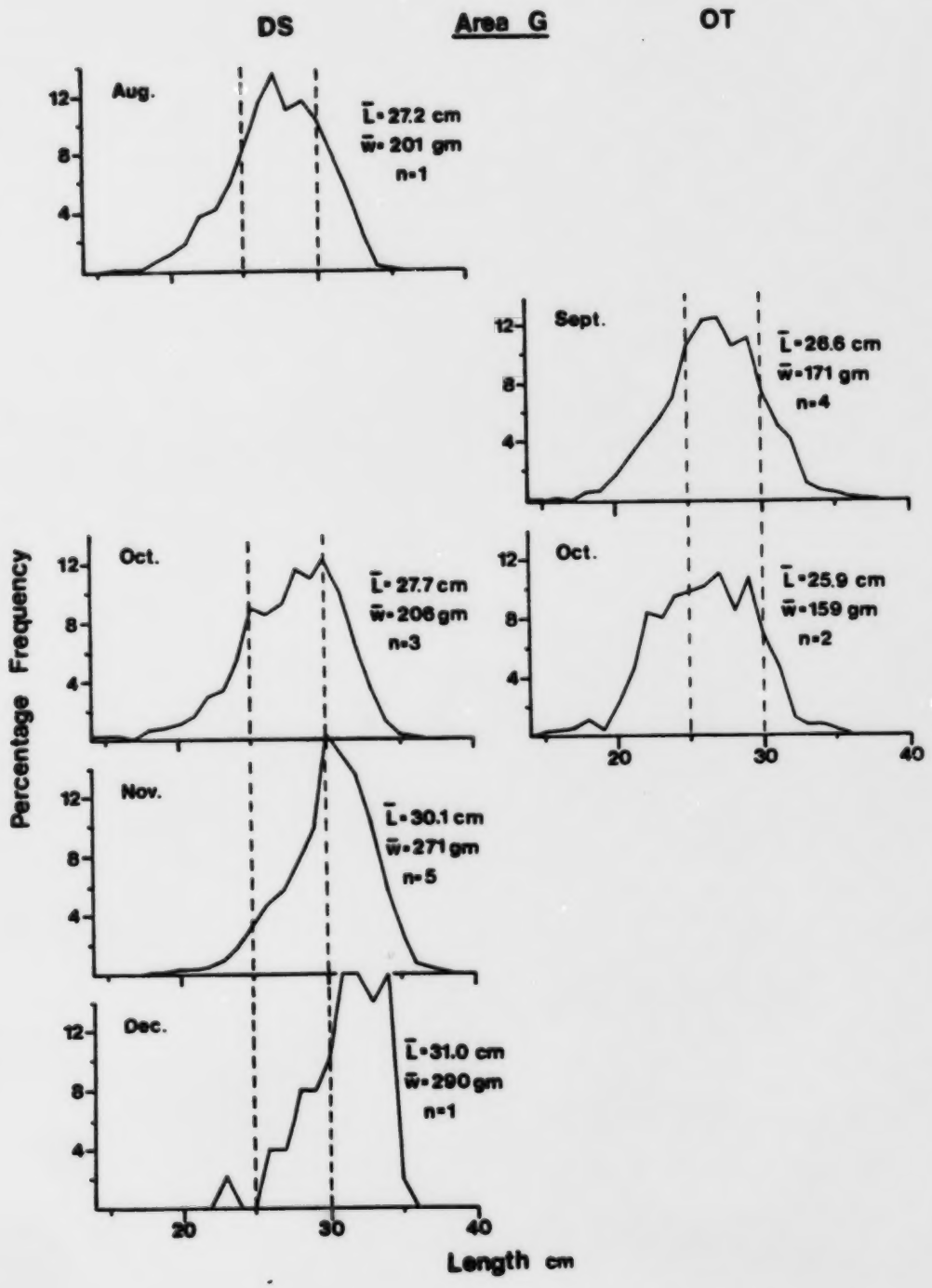

Fig. 8a. Length-frequencies of discards of American plaice in Div. 4T in 1976 by area, gear and month. ($\bar{L}$ = mean length, $\bar{W}$ = mean weight, n = number of trips sampled.) — AREA G.

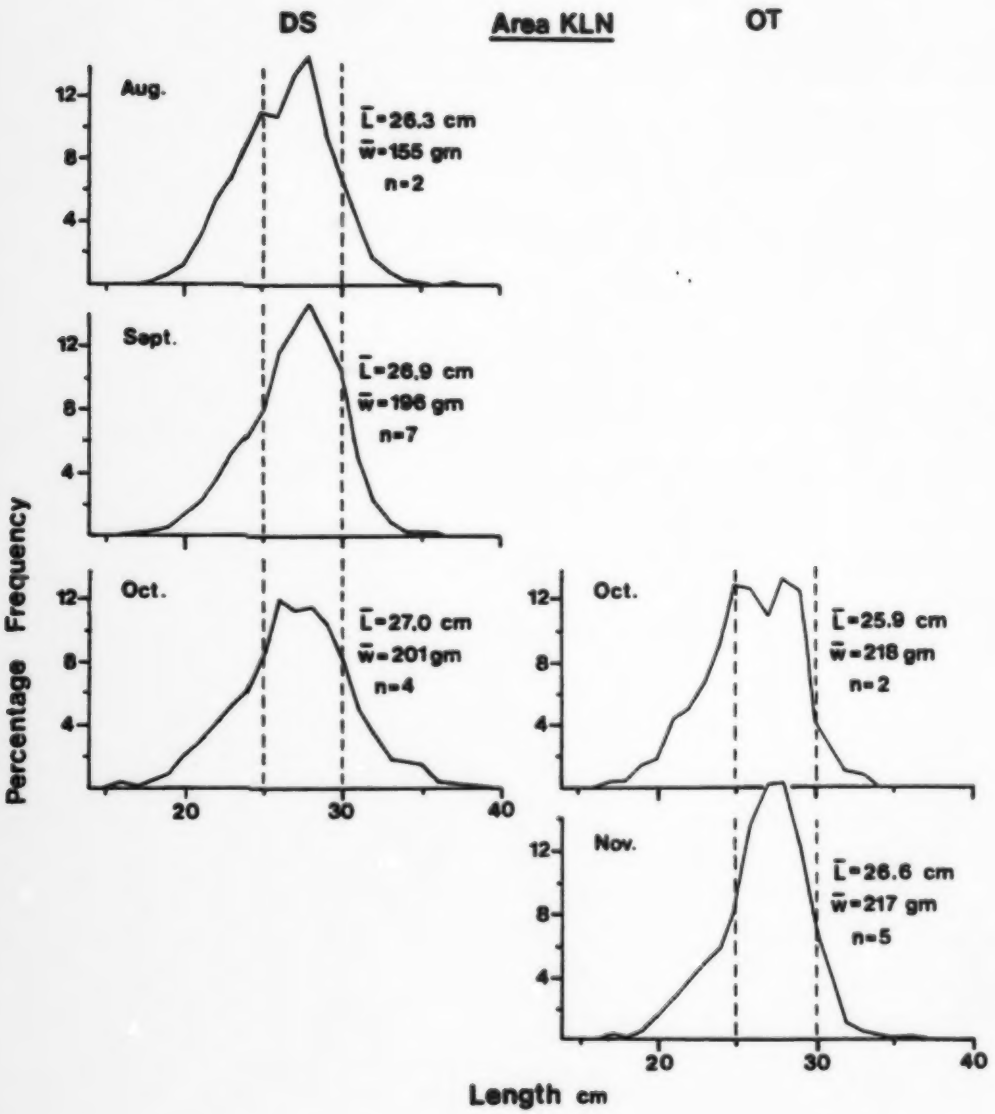

Fig. 8b. Length-frequencies of discards of American plaice in Div. 4T in 1976 by area, gear and month. ($\bar{L}$ = mean length, $\bar{W}$ = mean weight, n = number of trips sampled.) — AREA KLN.

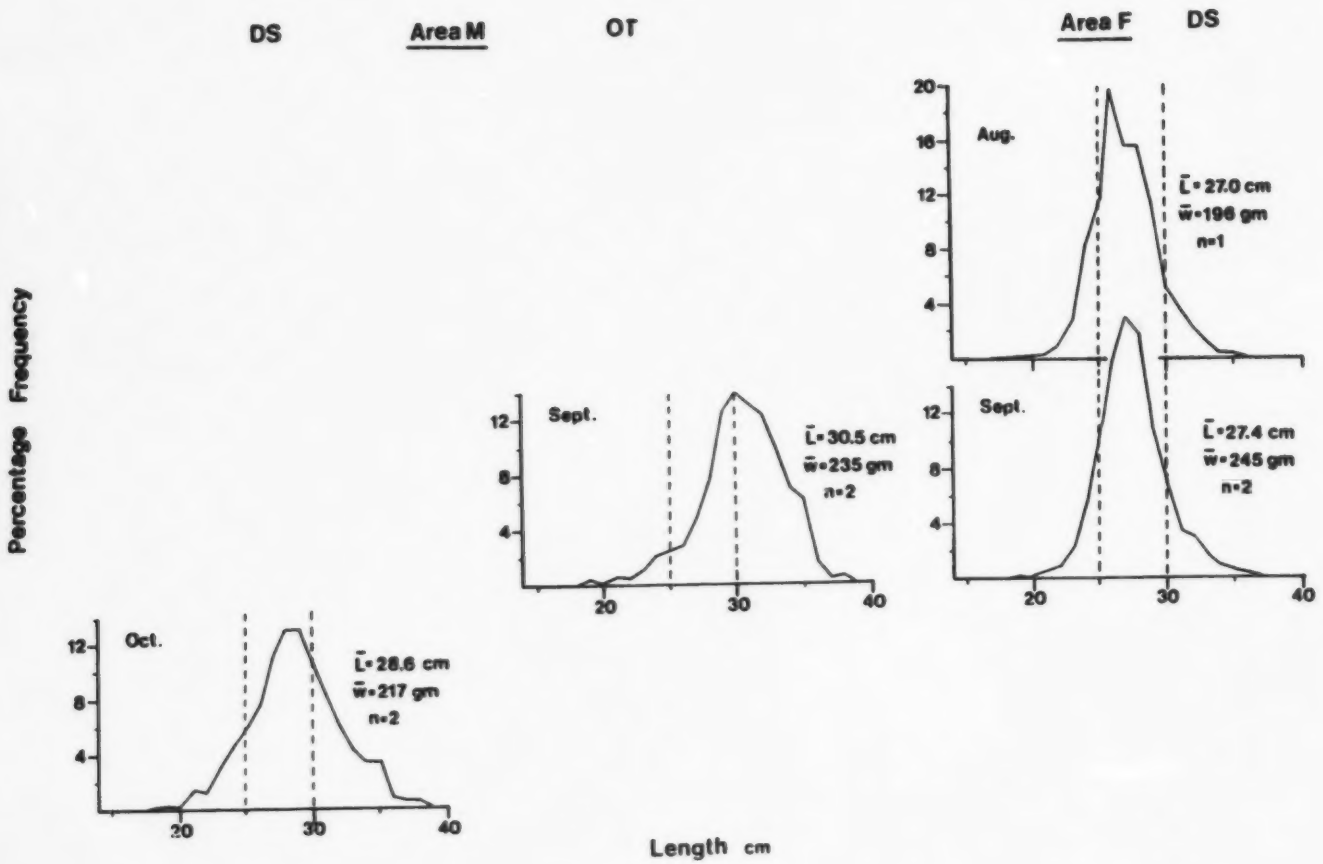

Fig. 8c. Length-frequencies of discards of American plaice in Div. 4T in 1976 by area, gear and month. ($\bar{L}$ = mean length, $\bar{W}$ = mean weight, n = number of trips sampled.) — AREAS M AND F.

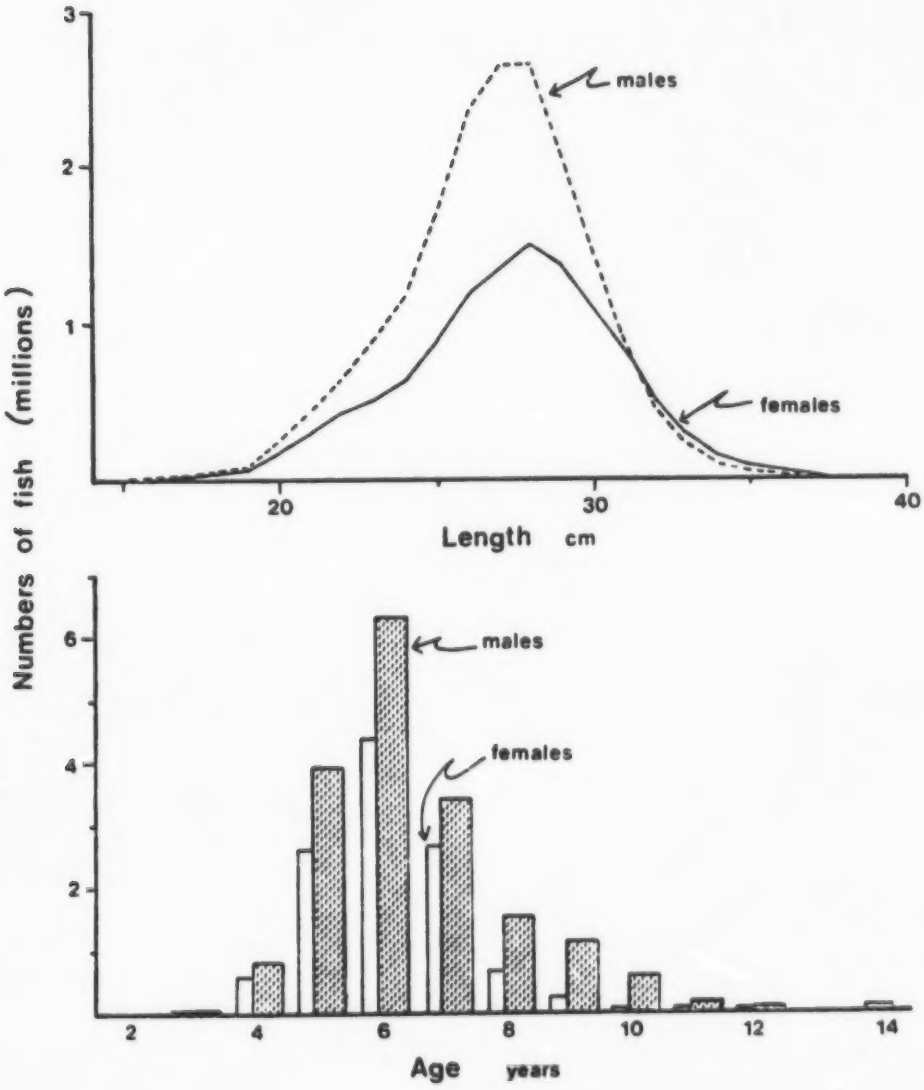

Fig. 9. Length and age compositions by sex of American plaice discards by Danish seiners and small otter trawlers combined in Div. 4T in 1976.

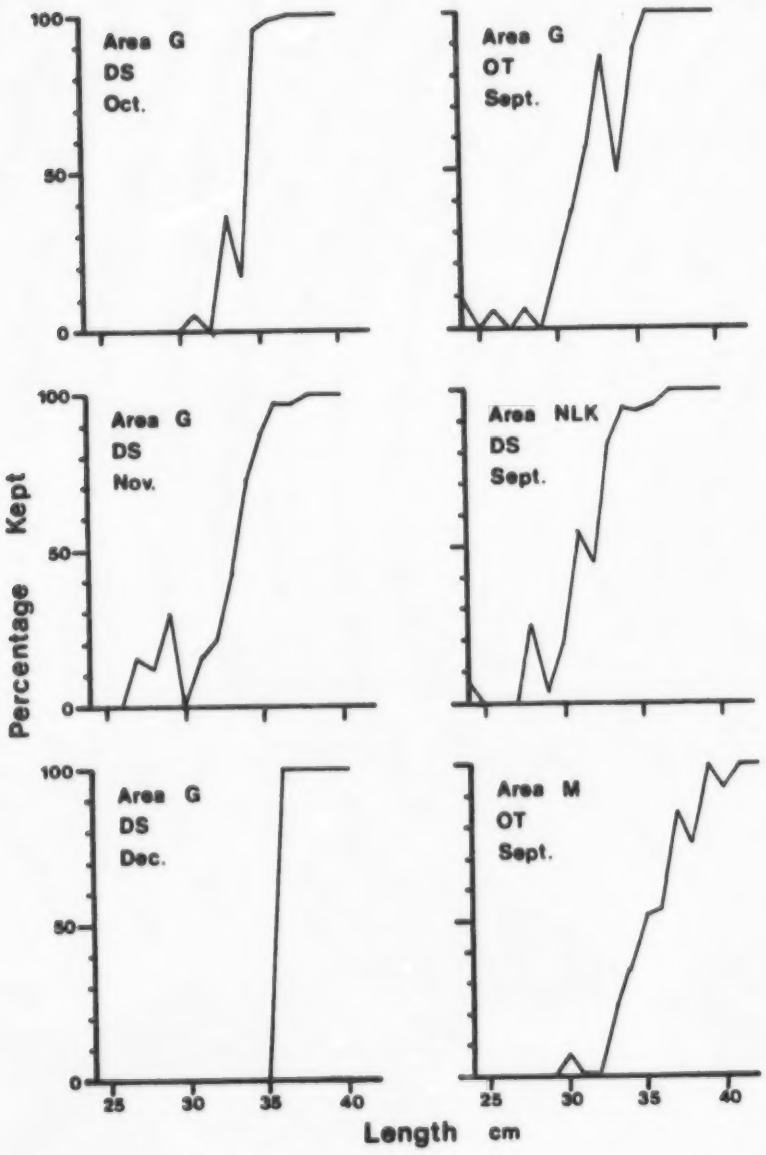

Fig. 10. Ogives of percentage at length of American plaice kept from catches in Div. 4T in 1976, by area, gear and month, based on sea samples of kept fish.

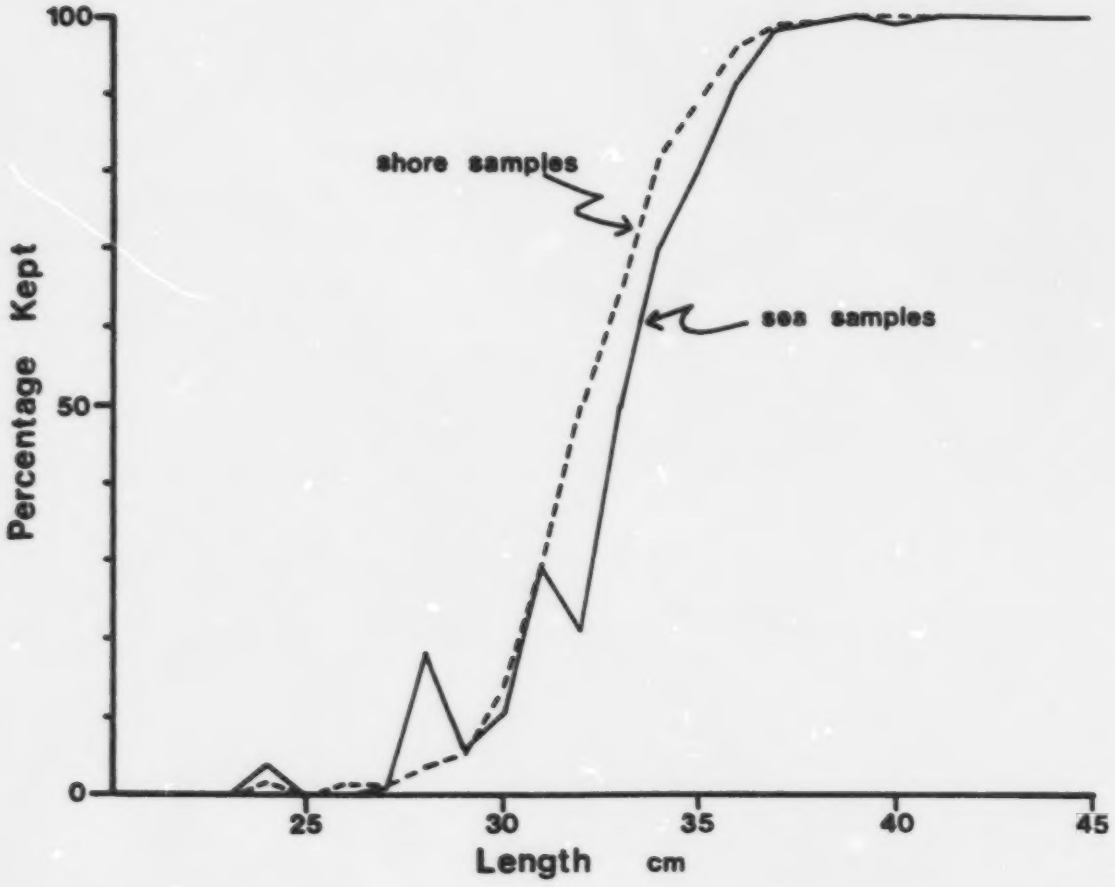

Fig. 11. Composite ogives of percentage at length of American plaice kept from catches in Div. 4T in 1976 based on sea samples of kept fish and on landings size compositions based on shore samples.

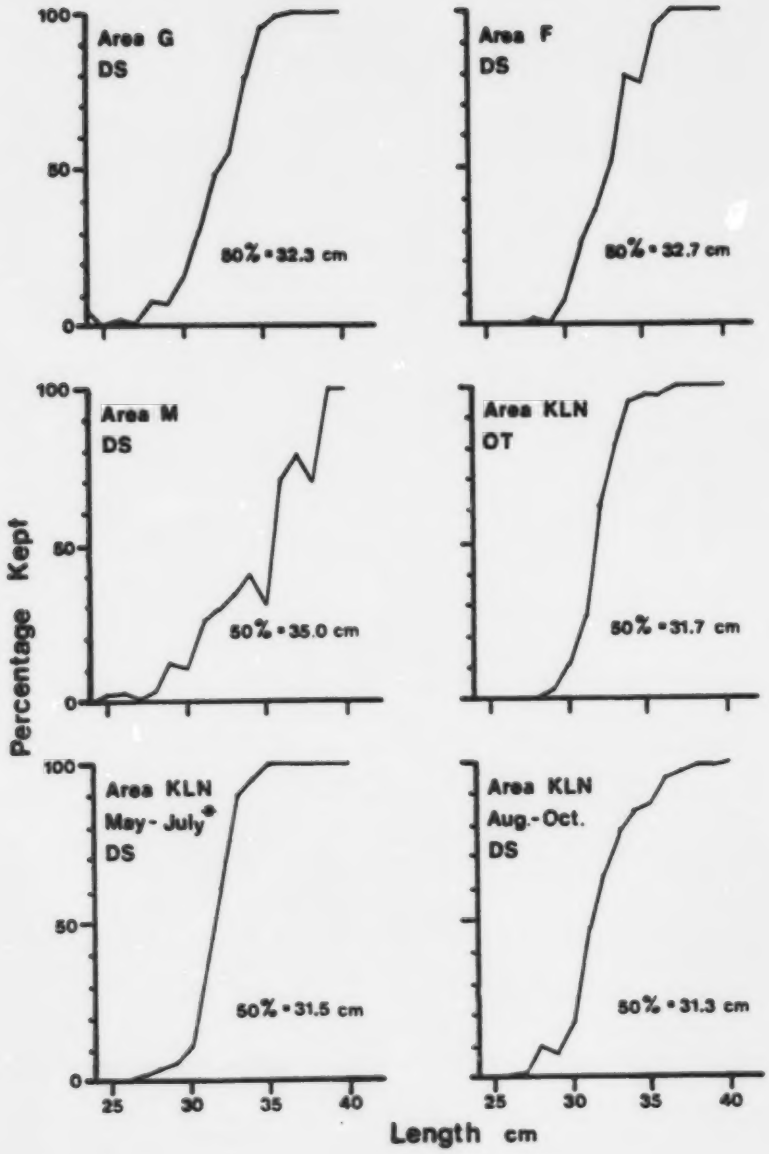

Fig. 12. Ogives of percentage at length of American plaice kept from catches in Div. 4T in 1976 by area and gear, based on shore samples of landed fish. (* Data not part of MacLaren Atlantic Ltd. study - see text.)

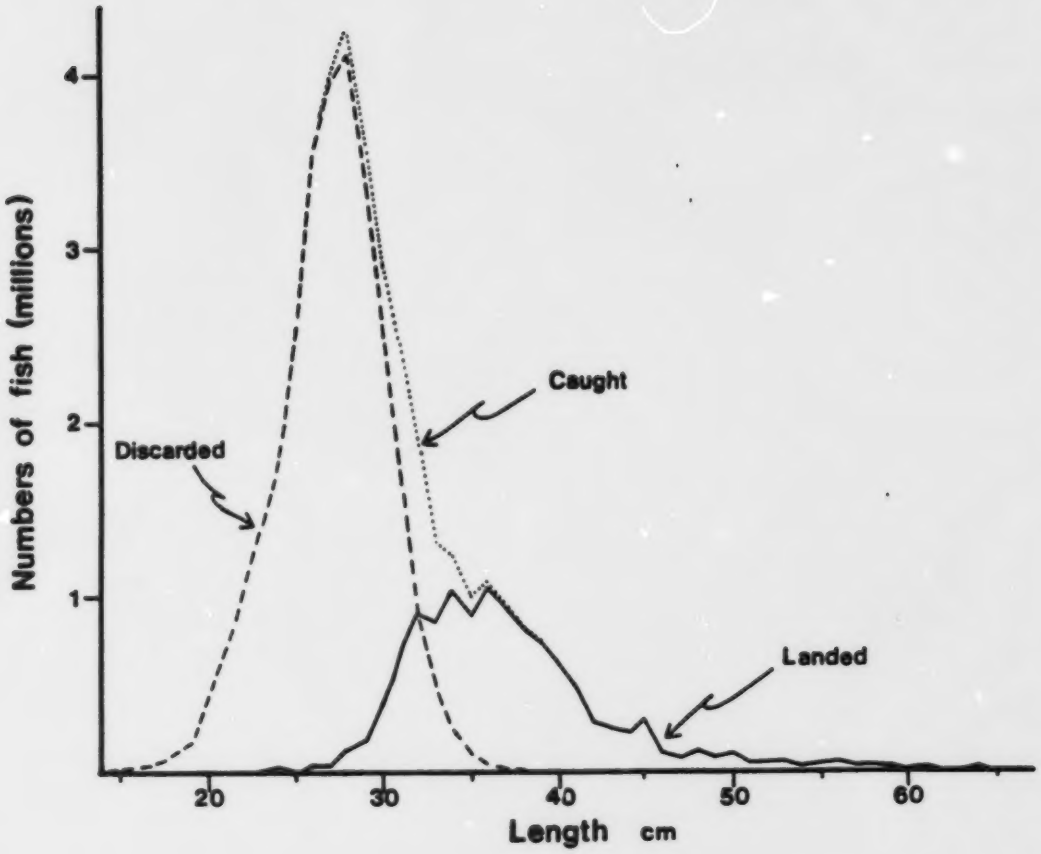

Fig. 13. Length compositions of American plaice catch, and of discarded and landed portions, by Danish seiners and small otter trawlers combined in Div. 4T in 1976.

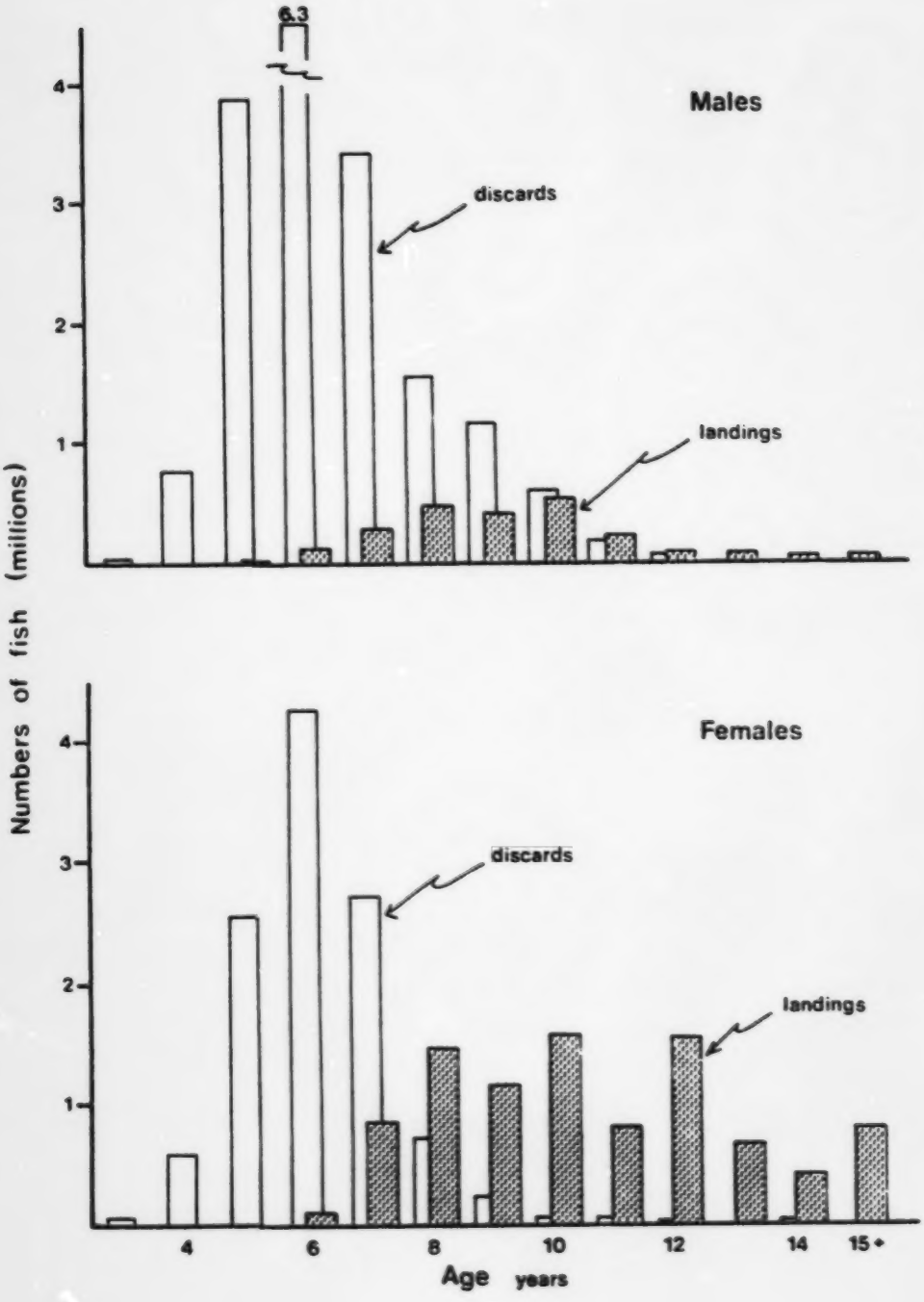

Fig. 14. Age compositions by sex of American plaice discards and landings by Danish seiners and small otter trawlers combined in Div. 4T in 1976.

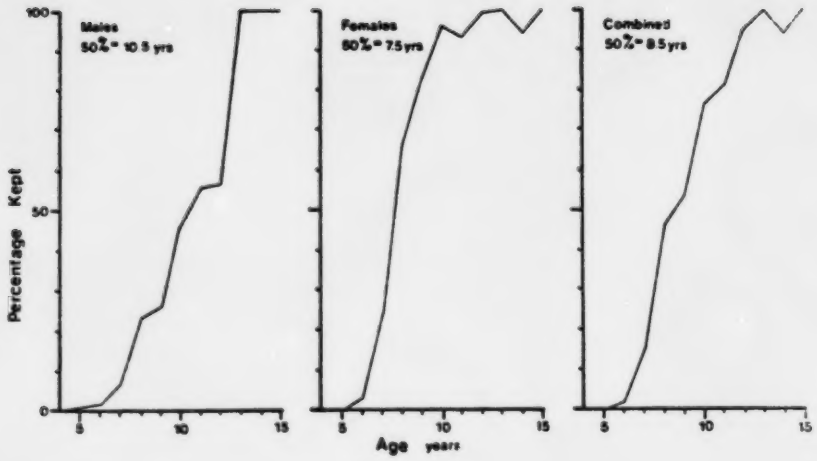

Fig. 15. Ogives of percentage at age of American plaice kept from catches by Danish seiners and small otter trawlers combined in Div. 4T in 1976, by sex and for sexes combined.

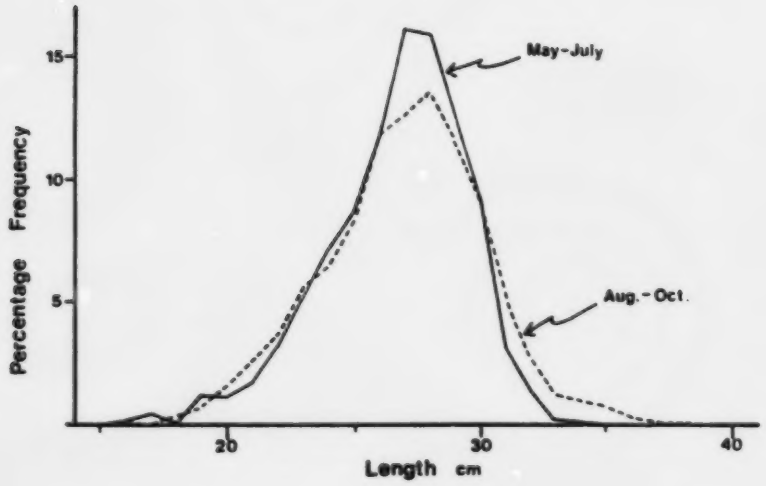

Fig. 16. Percentage length-frequency distributions of discards of American plaice by Danish seiners in May-July and August-October, 1976, in area KLN of Div. 4T.

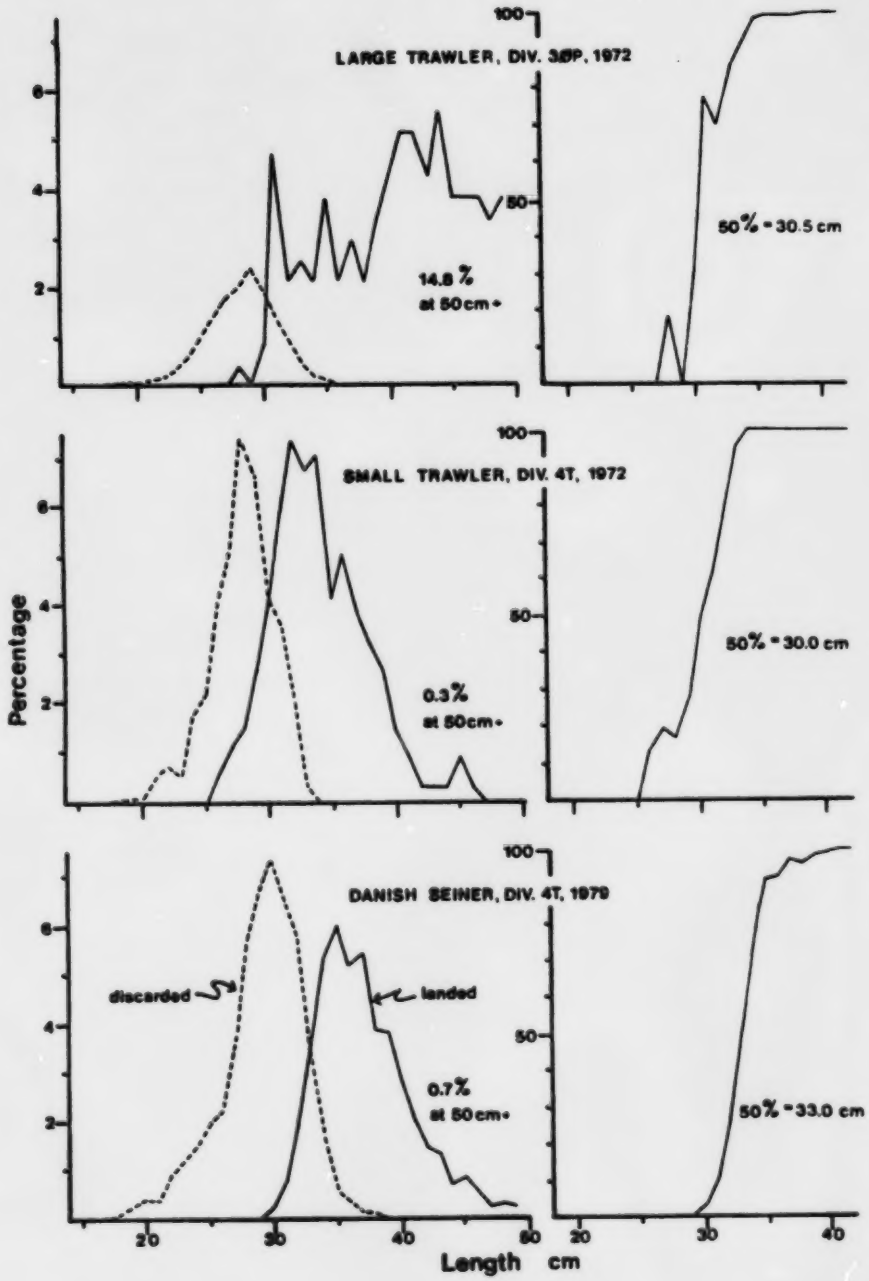

Fig. 17. Length-frequencies of discards and landings as percentage of total catch (left side), and cull ogives as percentage at length retained for landing (right side), for a large and a small trawler in 1972 fishing in Div. 3OP and Div. 4T respectively, and for a Danish seiner fishing in Div. 4T in 1979.

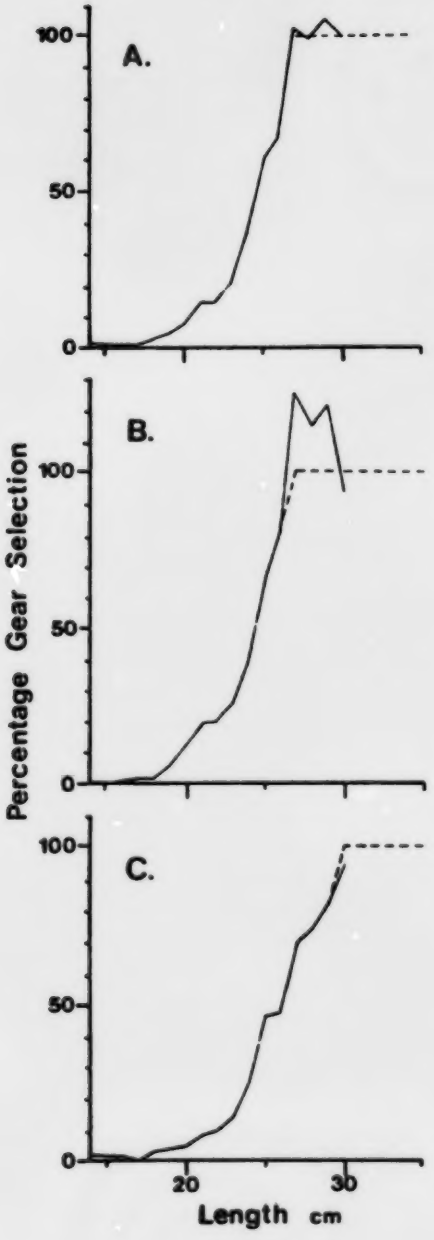

Fig. 18. Gear selection curves for American plaice in Div. 4T, 1976. A. for small otter trawlers and Danish seiners combined, B. for small otter trawlers and C. for Danish seiners, based on comparisons of commercial catch and research vessel survey population compositions. Dashed line illustrates assumptions of full recruitment of 27 cm in A and B, and at 30 cm in C.